UCLA SPACE PROGRAM DECEMBER 1967

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SPACE SCIENCE CENTER
INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS

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SPACE PROGRAM
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The Space Science Committee
W. F. Libby, Chairman

UNIVERSITY OF CALIFORNIA, LOS ANGELES

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I N T R O D U C T I O N

The Los Angeles campus of the University of California is in a unique position to offer greatly needed educational leadership and cooperation to the aerospace industry which is concentrated in the Southern California area. Faculty and research personnel, with headquarters at Slichter Hall, completed in January 1966, accommodate various graduate-level research activities and actively cooperate with NASA and industrial firms in their research projects and education pursuits.

By offering and supporting courses of instruction and research, frequently of an interdisciplinary nature, UCLA's space science program is able to assist other university departments and research units in their own programs as related indirectly to the space program.

This report includes summaries of space related research activities for the period ending December 31, 1967.

The research activities and facilities described herein and the faculty and professional research staff associated with these projects indicate the greatly enhanced potential UCLA has for pursuing a more vigorous effort in space-related research and education in the coming years.

Detailed progress reports on each project have been submitted to NASA and other supporting agencies and may be obtained from the principal investigators who contributed to this report.

NASA PREDOCTORAL TRAINING GRANT

NsG (T) 4-62

UCLA is completing its sixth year of participation in the NASA Predoctoral Research Training Program. During these six years, 26 NASA trainees have received the Ph.D. We feel UCLA has contributed substantially to NASA's goals.

During the academic year 1967-68, 40 graduate students are recipients of NASA Predoctoral Traineeships. Of that number, nine were awarded traineeehips which began with the Fall Quarter, 1967, for a period up to three years. These trainees and their fields of specialization are:

Berk, J.V.	-	Physics: high energy
Eskovitz, A.J.	-	Engineering: electronic systems, control systems, electromagnetic theory
Grace, C.D.	-	Zoology: genetics (molecular)
Gudehns, D.H.	-	Astronomy: aerodynamic effects
Jenkins, J.B.	-	Zoology: chemical mutagenesis, genetics
Richard, R.J.	-	Astronomy: astrophysics
Rischer, C.E.	-	Zoology: animal behavior and ecology
Slobko, T.A.	-	Mathematics: branch algebras, approximation theory
Watanabe, C.K.	-	Engineering: electrochemistry

The following trainees completed doctoral degrees by the beginning of the Fall Quarter, 1967:

Name	Dissertation Title
John S. DeGroot	Experimental investigation of electron runaway phenomena.
Samuel S. Fisher	Translational relaxation in free jets.
Norman B. Kramer	Non-reciprocal solid state plasma waveguides.
Richard A. McCray	Quasi-stellar synchrotron sources and intergalactic matter.
Ray R. Sayano	The electrochemical behavior of nickel, iron and nickel-iron alloys in sulfuric acid.
Lawrence A. Vredevoe	The anharmonic interactions of acoustics and infrared phonons and the effects of the phonon electric field on vibronic spectra and on the lattice-dipole interaction in KCI:OH.
David A. Wismer	Optimal control of distributed parameter systems using multilevel techniques.

THEORETICAL INVESTIGATION OF THE CONSTITUTION OF THE MOON AND PLANETS

NsG 216-62 (Kaula)

Thermal History of the Moon and Venus

W. H. K. Lee

Thermal models characterized by temperature-dependent fractionation and consequent upward migration of radioactive heat sources, previously applied to the earth, were adapted for application to the moon and to Venus. Both bodies were assumed to have a content of radioactive elements similar to type I carbonaceous chondrites.

Calculations of the thermal history of the moon were carried out assuming an initial temperature of 1000°C. If no fractionation is permitted, a temperature of 2300°K at the center is attained, and the melting point of basalt, about 1400°K, is reached at a depth of 200 km early in the moon's history. Subsequent cooling is only about 200°K, shifting the basalt melting depth to 300 km. The major effects of allowing for the upward fractionation of radioactive heat sources are 1) reduction of the maximum temperature at great depths, more than 1000 km, to less than 2000°K; and 2) a greater cooling at intermediate depths 200 - 700 km, so that the basalt melting depth is 500 km. These effects are mainly the result of a concentration of the sources around 250 km depth. If the initial temperature is assumed to be 0°C, then the present temperature is more than 100°C below basalt melting at all depths.

Calculations of the thermal history of Venus were carried out assuming a surface temperature of 600°K and an iron core of radius 2900 km. If no fractionation is permitted, then a maximum temperature of about 5000°K is attained at a depth of 2200 km; the melting point of dunite is exceeded at 300 km depth; and the melting point of basalt is exceeded at the very shallow depth of about 40 km. The major effect of allowing for the upward fractionation of radioactive heat sources is to reduce the temperature to the melting point of dunite at depths of 300 to 2400 km. However, given the high surface temperature of 600°K and any plausible thermal conductivity of the crust, it is unavoidable that there is general melting of basalt at a comparatively shallow depth in Venus. Either Venus has a weaker,

more fluid interior than the earth or an appreciably lower radioactive element content than any chondritic meteorites.

Problems of the Origin of the Terrestrial Planets

W. M. Kaula

A comprehensive review of theories of origin of the planets was undertaken with a view to identifying physical problems appropriate for more detailed attack.

The principal conclusion was that it is most probable that the terrestrial planets originated by condensation from a cold cloud of dust and gas with an average chemical composition between solar and type I carbonaceous chondrite. This cloud, the solar nebula, was shed by the unstable contracting sun, and then moved outward because of magnetic coupling to the rotating sun. The opacity of the nebula must have been considerable to permit the temperature to drop sufficiently to facilitate condensation of solid bodies. The relationship between the sweeping away of the excess gas, and possibly dust, and the stages of planet formation is unsure. Certainly there was ample energy wrapped up in the outer parts of the sun by the hydromagnetic momentum transfer process, and there is evidence from the HDLiBeB isotope ratios that part of this energy was expended in energetic particle outbursts when most of the hydrogen which remained was already in sufficiently condensed form to be shielded. Whether the sun was also the source of heat to accomplish reduction and volatization of the material in the planets and meteorites is dubious; the various disequilibria suggest that the reductions took place in condensed environments, where the heat would have been supplied by gravitational contraction of the planet or short-lived Al^{28} radioactivity or the pressure of accumulated gas.

The great question is the extent to which these condensed environments either have been destroyed, or have evolved into a present environment. As more of the pertinent facts are taken into account, it becomes more difficult not to complicate the answer with ad hoc mechanisms. Certainly there are a number of phenomena which suggest significantly different environments, some of them not only at different distances from the sun, but also necessarily at different stages anywhere from 10 to 10^8 years apart: the differing densities of the earth and the moon; the loss of volatiles of the earth with respect to chondritic meteorites; the differing iron contents of meteorite classes; the groupings in reduction of chondrites; the groupings in trace element content and isotope ratios of meteorites; the formation and inclusion of chondrules; the juxtaposition of gas-rich and

gas-deficient matter in some meteorites; the varying Xe^{129} excesses relative to the earth; the greatly different $[Co_2]/[H_2O]$ ratios in the earth and Venus atmospheres; the uniquely high moon/earth mass ratio; etc.

The narrowing down of the possible explanations (i.e., mainly number, size, and composition of protoplanets; size and composition of proto-atmospheres; etc.) will depend not only on new data such as the chemistry of the lunar surface material (will it all be carbonaceous chondrite?), but also on the more detailed solution of some physical problems. Those which appear to be most important are:

1) how does material condense and accrete from a dust-cloud in the solar nebula: the relative influences of temperature, gas pressure, turbulence, gravitational instability, electromagnetic effects? To what extent are comets pertinent to this problem?

2) what are the conditions of the hydromagnetic transfer of angular momentum in the nebula: the allowable ionization levels and the manner in which they are maintained; the time scale, and its relation to the time scale of solar contraction; the extent to which the field can be "wound up" in the sun before it breaks down; the necessary gas pressure to resist breakdown of the field in the nebula; the extent to which dust can be carried along with the gas; the influence of the magnetic field on condensation; etc.?

3) what happens when two objects collide at high energy levels: the effects of irregularities in allowing small solid pieces to be broken off; the cushioning effect of a large proto-atmosphere; the extent of melting and of vaporization in complete fragmentation; the extent of gas loss; etc.?

4) how can gas escape by mechanisms other than diffusion or evaporation: the extent to which an explosive blowing-off is required; the possibility of making the mechanism selective other than by condensation? Do similar mechanisms explain the loss of primordial atmosphere by the earth and the loss of hydrogen by the outer parts of the solar system?

5) what environments will significantly change the C/H ratio: non-equilibrium effects, as well as temperature, pressure, gravity, and the amounts of oxygen, nitrogen, and silicates present?

Spin-Orbit Coupling in the Solar System

P. Goldreich and S. J. Peale

In previous papers we showed that the rotation period of the planet Venus could be stably locked at 243.16 days retrograde by an interaction with the earth. Stability of this resonant rotation depends on a permanent second harmonic deformation of the planet which is comparable with that of the moon. The present work concerns capture of the planet into this resonance as its rotation period is driven toward the synchronous value (225 days prograde) by solid body tides. It is shown that trapping at the resonance can be understood if Venus possesses a fluid core similar to the earth's. Maximum capture probability occurs if the core responds to changes in angular velocity of the mantle with a time lag of about 3×10^4 years, which is the most probable period of libration of Venus about the resonant angular velocity. If Venus is in the resonant rotation state, then mapping of its gravitational field will determine the direction of its primordial rotation, an estimate of its magnitude, and the magnitude of the current tidal dissipation. If the primordial rotation was prograde, the calculated capture probabilities do not apply since the nature of the dissipative force required to drag the planet through the synchronous rotation rate would not be known.

The Zodiacal Light and Earth Orbiting Dust

S. J. Peale

The dynamical and observational properties of a geocentric dust cloud are discussed and compared with observations of the zodiacal light. The work was motivated by conflicting experimental estimates of the density of dust near the earth and by recent theoretical investigations which could justify only a minor increase in concentration over that in interplanetary space. It is shown that observation of the zodiacal light in the ecliptic plane cannot differentiate between heliocentric and geocentric dust clouds except that the appearance of the F Corona requires a cloud of dust about the moon if the zodiacal light is to be largely due to geocentric particles. On the other hand, observations of the zodiacal light off the ecliptic plane require the source of the zodiacal light to be heliocentric. Various rationalizations are considered which might salvage the hypothesis of a large contribution to the zodiacal light by geocentric dust. But each is shown to create another dynamical or observational inconsistency which is just as damaging to the hypothesis. The conclusion is therefore reached that the contribution of geocentric dust to the zodiacal light is

completely negligible and that the so-called dust belt of the earth is largely non-existent.

Orientation of Spin Axis of Planets and Satellites

S. J. Peale

Investigation of the asymptotic orientation of the spin axes of planets and satellites which are locked in resonant spin states of either of two kinds was started.

Geophysical Implications of Satellite Determinations of the Earth's Gravitational Field

W. M. Kaula

The largest departure from hydrostatic equilibrium (by a factor of 2) is the oblateness, which together with the observed rate of deceleration of the earth's rotation, leads to an estimate of about 10^{26} poises for the viscosity of the lower mantle. The remaining variations in the field are too large to be associated solely with the crust; their origin must be mainly in the mantle. The positive correlation with topography for spherical harmonic degrees $\ell \geq 6$ and the rate of decrease of the variations (proportionate to ℓ^{-2} in normalized potential coefficients, or to ℓ^{-1} in gravity anomaly power spectrum) are such that their source must in part be in the upper mantle, less than 400 km deep. However, the lack of obvious correlation with other indicators of upper mantle activity such as sea-floor spreading and heat flow suggests that the density variations are the consequence of relatively small imbalances between dynamic disturbing effects and compensating restorative effects. At least part of the variations, particularly for degrees $\ell \geq 5$, probably have their source in the stiff lower mantle.

The gravitational energy associated with the density irregularities implied by the gravitational field is not extraordinary on a geological time scale -- a few 10 million years' heat production by radiogenic elements, at most. Which indicates again that the density irregularities are more by-products of the interactions taking place within the earth than an important driving effect in themselves.

Progress in interpreting the broad variations in the gravity field appears to depend in identifying other indications of upper mantle motions and irregularities; constructing a satisfactory model to explain these indications; deducing the gravitational effects of the model; and subtracting them from the

observed field to leave a residue to be accounted for by the lower mantle. It is entirely possible, though, that a model of the upper mantle "satisfactory" in the sense of matching numerical data may never be completely attained because of intense localization of energy sources and strongly non-linear non-Newtonian flow because of stress-dependence of viscosity.

ANALYSIS OF DATA FROM MARINER-4 MAGNETOMETER

NGR 05-007-065 (Coleman)

Paul J. Coleman, Jr.

During the reporting period, reduction of the experimenter's extract tapes for the magnetometer experiments was completed. A study was initiated on the radial dependence of the interplanetary magnetic field. A detailed analysis was also undertaken of the properties of variations recorded in the field during the flight of Mariner 4. Properties such as the power spectra of vector components and the coherence and phase differences between pairs of vector components as functions of frequency will be determined. These results will be compared with the results obtained for a similar analysis of Mariner-2 magnetometer data.

In collaboration with the Mariner-4 experimenters at the University of Iowa, we also began a study of the correlations between variations in particle flux and variations in the field. At the same time, studies of variations in polarity distribution of the field were extended to include the last seven periods of solar rotation.

UCLA SATELLITE PROJECT

NSR 05-007-094 (Coleman)

Paul J. Coleman, Jr.

A proposal was submitted to NASA for the design and development of a new earth satellite with which to study the properties of collisionless, magnetized plasmas in space. It is intended to observe the properties of such plasmas by simultaneously measuring, with appropriate time resolution, as many as possible of the variables necessary to describe the state of the plasma. The observables are the electric and magnetic

fields and the directional spectral intensity of each species of charged particles. Therefore, it is planned to equip this satellite with plasma probes, energetic particle detectors, electric field meters, and magnetometers.

Shortly after submitting this proposal, UCLA issued a request for proposals from qualified industrial firms, for studies of the feasibility of such a satellite. Proposals in response to this request were received from five firms. These proposals were evaluated and three of the five were selected to perform studies.

Following the completion of negotiation of the prime contract between NASA and UCLA, the necessary subcontracts were negotiated. The studies have been completed and evaluated at UCLA. During the reporting period the final report on the feasibility study was completed by UCLA, the proposed project was reviewed by the Particles and Fields Subcommittee of the Space Sciences Steering Committee, and the project was put in Category I.

EXPERIMENT FOR THE EARTH SATELLITE OGO-E

NAS 5-9097 (Farley)

T. A. Farley

During 1967, construction, calibration, and testing of two flight units were completed, and one unit was installed on the OGO-E spacecraft. This instrument is designed to measure the intensity, spectrum, and pitch angle distribution of electrons above 50kev in the magnetosphere and magnetosheath. Output from this instrument will be closely correlated with the UCLA magnetometer on the same vehicle in order to study particle-field interaction phenomena in detail. The launch of this spacecraft is scheduled for early spring 1968.

EXPERIMENT FOR THE EARTH SATELLITE OGO-E

NAS 5-9098 (Coleman/Farley)

Paul J. Coleman, Jr., T. A. Farley

This experiment was designed to provide simultaneous measurements of variations in the geomagnetic field and

variations in the directional spectral intensity of magnetically trapped particles. During the reporting period, all units were qualified and delivered to the spacecraft contractor, TRW Systems. Launch is expected in February 1968. At the same time, tests on the breadboard model of this magnetometer were continued.

SYNCHRONOUS-SATELLITE (ATS-1) MAGNETOMETER EXPERIMENT

NAS 5-9570 (Coleman)

Paul J. Coleman, Jr.

The primary scientific goals of this experiment are: (1) the determination of the dependence of the configuration of the distant geomagnetic cavity upon the sun-earth-satellite angle, and (2) the determination of the dependence upon this angle of the production, characteristics, and propagation of magnetic and hydromagnetic disturbances in the distant magnetosphere. The satellite ATS-1 has been in orbit for one year and has been returning data since early in 1967. The analysis of the data during this reporting period included the measurement of the quiet-day diurnal variation of the geomagnetic field in the synchronous, equatorial orbit, observations of the magnetopause and magnetosheath at 6.6 earth radii, studies of low-frequency magnetic-field oscillations, studies of bay-associated events at ATS-1, and studies of magnetic storms.

PARTICLES IN SPACE

NsG 249-62 (Farley)

T. A. Farley

Instrument Development

This grant continues to support laboratory activities on a modest level to design, evaluate, and test portions of future particle detection experiments for space use. During 1967, most of this activity consisted of the evaluation of the vastly improved miniature photomultiplier tubes which have come on the market. Their small size and low noise will permit thicker shielding for the same shielding weight, and lower energy

thresholds for particle detection. We have also undertaken the development of a very fast, high gain, current mode amplifier in an attempt to widen the dynamic range of space particle detection systems. The development of this amplifier is in the hands of Alan Eskovitz, a NASA trainee, and this development is his Ph.D. problem in the UCLA Electrical Engineering Department.

Radiation Monitors on the OVI-2

In 1967, this grant was supplemented with funds to analyze the data from five radiation instruments of our design on the OVI-2 Air Force satellite. During the year, we have made machine plots of all the data, and have abstracted data from the plots to be organized and presented in meaningful fashion. We are presently preparing the first of several papers on this experiment, and will also present our conclusions at the spring meeting of AGU in April, 1968. This scientific presentation will represent the first completed space radiation experiment done by our group.

FIELDS IN SPACE

NsG 249-62 (Coleman)

Paul J. Coleman, Jr.

Analysis of Data from Mariner-2 Magnetometer

Studies of the records obtained with the Mariner-2 magnetometer and plasma probe were continued. During the reporting period the radial flux of angular momentum associated with the measured plasma fluctuation was estimated. A model for a turbulent solar-wind expansion was also developed on the basis of these measurements.

Efforts to develop a model for the diffusion of cosmic rays were continued. In this work, an attempt is being made to derive the diffusion coefficients from the observed properties of the interplanetary magnetic field.

Measurements of Acoustic and Magnetic Disturbances in the Ionosphere

The purpose of the initial phase of this project is to employ ground-based detectors to study experimentally the propagation of disturbances produced artificially in the ionosphere. More specifically, we have been concerned with disturbances produced by rocket engines in the ionosphere. Most of the work on this project has been supported by NASA under a separate grant. However, the required electronics work has been supported under research grant NsG 249.

Work on this project was halted, at least temporarily, since no students are presently available to extend the work of those who recently completed their graduate studies.

Mariner-Venus (1967) Magnetometer Experiment

Preparations for this experiment were completed during the past year. The Mariner 5 was launched on June 14, 1967, and passed Venus on October 19. The experiment operated properly during the entire mission and is still doing so.

Development of New Instruments

During the past year, the design of a magnetometer for attitude-stabilized satellite at synchronous altitudes was undertaken. This instrument will be a modification of our existing OGO-E and ATS-1 instruments.

An electronic current that simulates the output of magnetometer probes of the fluxgate type also was completed. Research into the physics of these probes again was taken up following the halt due to the utilization of our test facilities for flight programs.

EXPERIMENT FOR THE EARTH SATELLITE OGO-F

NAS 5-9308 (Farley)

T.A. Farley

During 1967, two units of this instrument were built. At present, one has been calibrated and is undergoing prescribed qualification testing. The second unit is now being calibrated at UCLA. This instrument is similar to the one on the OGO-E spacecraft, but is designed for a low altitude polar orbit, and will detect electrons of the same energy range being precipitated

into the atmosphere from the radiation belts. We expect that its time in orbit will overlap OGO-E, so that some important spatial correlations may be made. Launch is scheduled for the end of the year 1968.

EXPERIMENT FOR FUTURE AIR FORCE SATELLITE

AF29-601-67-C-0064 (Farley)

T. A. Farley

This Air Force contract permitted the OGO-E prototype to be modified and recalibrated for use on a future Air Force vehicle. This work is complete, except for a minor portion of the calibration effort. No specific spacecraft assignment has been made for this instrument. We hope that something may be found during 1969.

At the present time, a contract is being negotiated for data reduction on the five radiation instruments on the OVI-12 spacecraft, which was launched in August 1967. The mission of this satellite has been to study the high energy particles from solar-flares.

CHEMISTRY OF METEORITES

NsG 313-63 (Wetherill)

The Distribution of Trace Quantities of Ge Between Iron, Silicate and Sulfide Phases

G.W. Wetherill, C.M. Wai, W.G. Ernst and J.T. Wasson

The discovery of Ga-Ge groups in iron meteorites has made the study of the geochemistry of Ge important for genetic considerations. The cause of the "quantization" of Ge content in iron meteorites must be related to the theory of the origin of such meteorites. A laboratory study on the equilibrium distribution of trace amounts of Ge between iron-silicate and Fe-FeS phases at controlled temperature, pressure and oxygen fugacity has been carried out. Olivines of varying compositions were synthesized, with Ge^{68} labeled Ge substituted for a small fraction of the Si. The distribution of Ge following an

experiment was determined by separation of phases and counting the Ge^{68} activity in the separated phases.

At oxygen fugacities where iron and olivine can co-exist, Ge is strongly siderophile even at the equilibrium P_{O_2} of iron-wustite at 900°C and 500 bars. With 10% of Ni in the iron (Fe-Ni alloy), the equilibrium P_{O_2} of iron-wustite increases by about 25%, a small change which does not seem to affect the siderophilic property of Ge. A similar siderophilic behavior of Ge was also observed in the Fe-FeS system. From these results, it seems that a simple one stage oxidation-reduction process is unlikely to cause the extremely low Ge content in some iron meteorites (iron meteorites of Ga-Ge group IV-A and IV-B). Some thermodynamic calculations on the oxidation-reduction of Ge at various temperatures also have been made.

Time of Fall of Stone Meteorites

G. W. Wetherill

The local time of fall of a meteorite is the most accurately determined parameter which is related to its orbital elements. If time of fall statistics are restricted to daylight falls, they should be relatively free of social effects. It is found that the fraction of day-light chondrites which have fallen in the afternoon (f) is 0.67, whereas for achondrites f = 0.41.

Because of their short (0-100 million year) cosmic ray exposure ages, it is likely that stone meteorites are fragmented from bodies in earth-crossing orbits. A modified form of Arnold's Monte Carlo procedure has been used to follow the orbital evolution of fragments ejected from various earth-crossing bodies. The distribution of local time of fall was calculated for those runs which terminated in earth impact.

The 10 earth-crossing (Apollo) asteroids (including 1580 Betulia and 1948 EA) yield values of f ranging from 0.27 (Icarus) to 0.53 (Geographos). Matter ejected from the moon into heliocentric orbits in random directions at velocities ranging up to 3.5 Km/sec gives f = 0.51. Lunar matter ejected at 3.5 Km/sec entirely in the direction of the earth's motion gives f = 0.54; matter similarly ejected in the backward direction yields f = 0.49. For fragments of Encke's comet, f = 0.38.

Almost all of these sources are consistent with the achondritic data, none with the chondritic data. It is possible to contrive hypothetical orbits which match more nearly the excess of afternoon falls characteristic of the chondrites. These orbits have low inclination, perihelia only slightly within

the orbit of the earth and aphelia in the vicinity of 4 A.U. No bodies are known with orbits of this kind. Because of their large aphelion distance it would be very difficult to discover solid bodies in such an orbit, even if they had diameters as large as 30 Km, and it may be that a significant number of such undiscovered objects exist in the solar system. It is necessary that the dynamical lifetime of the hypothetical objects be short, i.e. comparable to the chondritic cosmic-ray exposure ages. This requires a continuing source for these objects. Hilda and Trojan asteroids, as well as comets of Jupiter's family, are possibilities. However these sources also present major difficulties, only one of which is that the present Monte Carlo techniques are not reliable for tracing the evolution of the orbits of these bodies.

Rubidium-Strontium Ages of Normal and Shocked Hypersthene (L) Chondrites

K. Gopalan, G. W. Wetherill

Five normal grey hypersthene chondrite falls were analyzed for Rb, Sr and Sr isotopic composition. One (Bath Furnace) has a very low Rb/Sr ratio and Sr^{87}/Sr^{86} ratio (0.706). The spread in Rb/Sr ratios permits determination of an isochron for L-chondrites alone, without resort to achondrites and assumptions of cogenesis. An age of 4.45×10^9 years (= 1.39×10^{-11} yr^{-1}) and initial Sr^{87}/Sr^{86} ratio of $0.7000 \pm .001$ are measured. Blanks are 0.2-0.6 and 1-3 nanograms for Rb and Sr respectively in processing about 300 mg of sample.

Rb-Sr measurements were made on 13 other hypersthene chondrites which show evidence of considerable shock and reheating or have very low gas retention ages. Four of these lie on the isochron above, the remainder uniformly plot above it. Of the 5 observed falls, 4 lie on the isochron while Ergheo, recovered five years after its fall, deviates considerably. Two badly weathered but unshocked gray L chondrite finds with high (3.5 b.y) gas retention ages plot only slightly above the isochron. It appears that gross chemical weathering alone does not explain all the observed deviations from the isochron, but it has not been possible to resolve the more subtle terrestrial Rb/Sr fractionation from that due to events in space.

UNDERSTANDING THE EVOLUTION OF THE UPPER MANTLE OF THE EARTH AND EVOLUTION OF THE INNER AND OUTER PLANETS

ONR N00014-67-A-0111-0001

NsG 314-63 (Kennedy)

G.C. Kennedy

The primary aim of our researches at high temperatures and pressures for the past several years has been that of attempting to understand the evolution of the upper mantle of the earth, and, by extension, the evolution of the inner and outer planets. We must know depths in the earth at which melting first takes place, the sequence of phase changes in silicates, and other liquid-solid transitions which may be of importance to understanding the structure of the planets. Our work has taken a number of directions and a substantial number of results have been obtained which are immediately applicable to the problem of the structure and evolution of the crust of the earth and to the problem of the chemistry of the surface of both the inner and outer planets. Because of these results, our immediate research aims and goals have changed, since some problems have been solved and others have arisen. A number of results obtained in our laboratory in the last year stand out as most important.

First, we have achieved a very large and somewhat unexpected increase in the range available for high pressure experimentation. A little more than a year ago the maximum pressure obtainable was 40-50 kilobars in piston-cylinder apparatus. Today we are working to 80 kilobars. This almost doubling of the pressure range resulted from a systematic study of the mode of fracturing of tungsten carbide.

We found that if the length:diameter ratio of pistons could be kept sufficiently small, the pistons resisted failure to much higher pressures. More recently a careful study of dilation of tungsten-carbide of various grades has showed the very clear superiority at extremely high pressures of pistons with much lower cobalt content. Consequently we are now using 3% Co pistons rather than our earlier pistons with 5.6% Co. Not only do these low cobalt pistons allow us to achieve higher pressures, but because of decreased dilation at high pressures the friction between our pistons and the carbide pressure vessel is much reduced. Unfortunately, the improved piston behavior and higher

available pressures immediately showed up deficiencies in our pressure vessel design, as our old pressure vessels simply would not accept the new available pressure region. An extensive computer analysis of pressure vessel design was then undertaken. As a result, new pressure vessels, utilizing support rings of the recently available grades of maraging steel of greatly increased strength, have been built and our entire apparatus now works to the new pressure limit of 80 kilobars.

Faced with the sudden and unexpected opening up of a new pressure region, we elected to defer work on some projects and make some urgently needed measurements in the new pressure region. Of primary importance was the redetermination of the pressure of transition in barium. The barium transition is widely used as a fixed point in the calibration of high pressure apparatus. A number of years ago this transition was taken as occurring at 79 kilobars but we showed several years ago that it was almost certainly as low as 60 kilobars. In recent years the value set for this transition has ranged from 53 to 60 kilobars. Consequently there has been great uncertainty in reported pressures from multiple-anvil apparatus where barium is used as a calibration point. We have redetermined the barium transition and find it to be at 55.0 $\pm$ .2 kilobars.

Probably one of the most important gaps in the understanding of the evolution of the inner and outer planets is the lack of knowledge concerning the effect of pressure on the melting of solids. Precise knowledge of this effect would enable us to estimate the minimum depths in the earth from which basaltic lava is produced and knowledge of the effect of pressure on the melting of iron would give us the temperature of the core of the earth at the inner-outer core boundary in the earth, which almost certainly corresponds to the solid-liquid transition in iron at 3 megabars pressure. The various estimates of the temperature of melting iron at 3 megabars have ranged from 2,800°C to 10,000°C over the last 10 years with drastic consequences to views on the evolution and thermal history of the earth.

We investigated this problem a few years ago and showed that for most solids the melting temperature was linear with the volume of the melting solid. This new melting "law" was sharply in contrast to predictions of the Simon equation generally used to predict the effect of pressure on melting. Thus with the extension of the pressure range from 40 to 80 kb, we immediately elected to test our melting law over the new interval and to reexamine the effect of pressure on the melting of iron to the limit of obtainable pressures. We have completed work on lithium, rubidium, sodium and potassium. Only sodium appears to obey the new melting law to 80 kb but the other alkalai metals

all show maxima in melting temperature at pressures in the 60-80 kb region. This was totally unexpected and the geophysical implications of this are not yet entirely clear. This unexpected turn of events dictates that the melting of a substantial additional number of elements and compounds be examined to the limit of available pressures.

Experimental work on natural rock systems has continued. The only natural samples of the deep mantle of the earth are the cognate zenoliths that occur in the diamond pipes of Africa. We have recently examined the origin of these diamond deposits and developed the evidence that they contain samples of the deep mantle of the earth, derived from a depth of at least 200 kilometers. The partial fusion of these rocks at pressures to 40 kb has been investigated. We have shown that the first product of partial fusion of these rocks ranges from tholeiitic basalt to picritic basalt. This finding is completely concordant with all the geological evidence that basalts are the primary rock erupted to the surface of the earth. This generates the important question of the bulk chemistry of the crust of the earth. If the evidence for our study of the partial fusion of deep mantle rocks is to be taken at face value, the bulk chemistry of the crust can only be basaltic - not granitic. Thus granites can only be explained as resulting from refusion of sediments chemically differentiated by an erosion cycle. The implication of this evidence is that basalts should be common on the surface of the Moon, Mars and Venus but no granites should be found or are to be expected, as available evidence suggests these planets have never been subjected to lengthy erosion cycles involving a hydrosphere.

FEASIBILITY STUDIES ON COORDINATED RADIATION EXPERIMENTS FROM METEOROLOGICAL SATELLITES

NGR 05-007-041 (Sekera/Hariharan)

Z. Sekera, T. A. Hariharan

The main objective of this project is to carry out experimental and theoretical investigations on the determination of atmospheric aerosol content and distribution through the polarization characteristics of the scattered radiation in the visible spectrum and coordinate the results of visible radiation measurements with those of infrared data to improve their information content. To realize this objective, a polarimeter has been designed and constructed to make ground-based and high-altitude measurements of skylight polarization. Extensive

measurements have been taken from the ground at China Lake, California, during December, 1967, and from NASA Convair 990 aircraft flown over various target areas in the United States during May and June, 1967. The results obtained from these measurements have been quite encouraging. To obtain useful information about aerosol content and turbidity, systematic measurement of the polarization characteristics must be carried out. More extensive measurements and comparison with theoretical values of ideal conditions will be required for perfecting the technique of the inversion process.

Theoretical studies indicate that the effect of aerosol scattering can be regarded as a perturbation of the polarization field of a pure molecular atmosphere. The difference between the measured values and those derived from the theory of Rayleigh scattering would provide a set of values from which the effective parameters relating to aerosol content, atmospheric turbidity, etc., can be determined. The theoretical investigations are being continued.

VISIBLE RADIATION POLARIZATION MEASUREMENTS

NAS 9-7267 (Sekera/Hariharan)

Z. Sekera, T. A. Hariharan

As of July 1, 1967, a contract was entered into with NASA Manned Spacecraft Center, Houston, for the design and development of a polarimeter for the Apollo Applications A mission. A subcontract was let to General Electric Company, Valley Forge, Pennsylvania, for the engineering design with the project staff at UCLA providing the necessary technical guidance and management, and carrying out support studies for the overall project. The contract has been satisfactorily completed according to schedule. The outcome of this six-month effort is the engineering design of a polarimeter instrument for satellite applications with several unique features to satisfy the scientific objectives of the experiment. All the features incorporated in the design have been tested with breadboards and, wherever possible, advantage has been taken of the past experience of General Electric in spacecraft technology. This contract is expected to be followed by another for construction of space-qualified instruments for the satellite experiment.

THE MEASUREMENT OF FLUCTUATING MAGNETIC FIELDS IN SPACE

JPL 950403 (Holzer)

R. E. Holzer

The Orbiting Geophysical Observatory Search Coil Magnetometer Program was designed to measure magnetic fluctuations in space within some 20 earth radii of the earth from near the minimum of the solar cycle in 1964 to near the solar maximum in 1969. The magnetometer frequency range from .01 to 1000 hz was chosen to explore signals in a region not studied at the time the program was initiated. An examination of the origin, character and distribution of plasma waves in the stated frequency range is of basic importance in testing theories of the collisionless bow shock, the magnetopause and the magnetosheath, as well as wave-particle interactions both within and without the magnetosphere.

At the present time there are four OGO satellites in space, OGO-1 and OGO-3 in eccentric orbits with apogees in excess of 20 earth radii and OGO-2 and OGO-4 in low altitude polar orbits. Meanwhile the fifth OGO is in preparation for launch during the late winter of 1968 and the sixth, late in 1968 or early in 1969.

In the initial phases of the program and through 1967, a large fraction of the effort has been devoted to processing some 4,000 data tapes received from satellites now in orbit. However, several analytical studies have been undertaken.

The distribution of magnetic fluctuations in the 1 to 1,000 hz range has been examined. Within the magnetosphere the regions of activity lie principally between L values of 2 and 7. In this region the search coil magnetometer is examining only the lower frequency range of a broader distribution. The outer part of the magnetosphere is usually quiet but the magnetosheath is characteristically disturbed. The average spectrum falls rapidly as the electron gyro-frequency is approached suggesting that a large fraction of the energy lies in electron cyclotron or "whister" waves. The intensity of the fluctuations fall sharply at the bow shock and the magnetopause boundaries. Precursor waves of the shock are observed in the interplanetary medium. The geomagnetic tail is relatively quiet with occasional bursts of energy observed near the neutral sheet.

A number of specific studies are in progress. These include a detailed examination of the structure of the bow shock, studies of special monochromatic bursts of energy in the magnetosheath, analysis of the motion of the magnetopause and its

effect in modulation of the plasma wave pattern, a study of the distribution of energy in the 1 to 1,000 hz range in the magnetosphere for investigating the wave particle interaction in the particle trapping region, and a study of the motions in the tail and the distribution of magnetic noise particularly within the region of depressed field which lies above and below the neutral sheet.

OGO-3 observations during January, 1967, happened to be made simultaneously with the unusual observation of a magnetopause crossing at 6.6 Re reported by the ATS-1 satellite. The extreme depression of the magnetopause has been doubted by some; however, the position of the shock observed by OGO-3 within about an hour of the ATS-1 event supports the hypothesis that the ATS-1 did, indeed, observe a magnetopause crossing unusually close to the earth.

The data from OGO-1, OGO-3, and OGO-4 have proved generally satisfactory. The digital data from OGO-2 has been plagued with interference from the satellite. Since OGO-4 was launched into an orbit comparable to OGO-2 during 1967, and since the OGO-4 records are very good, OGO-2 digital data analysis has practically ceased. It is anticipated that correlated data studies using OGO-3 and OGO-4 will be possible.

The program has been carried out in collaboration with Dr. E. J. Smith of the Jet Propulsion Laboratory. Five graduate students, Malcolm G. McLeod, Kenneth I. Brody, Christopher T. Russell, John V. Olson, and Ranae Burton are actively participating in the program.

INVESTIGATION OF TECHNIQUES FOR ANALYSIS OF ANCIENT SEDIMENTS AND EXTRATERRESTRIAL MATERIALS

NGR 05-007-077 (Kaplan)

I. R. Kaplan

Progress during the past year consisted of refining sample-handling techniques and the examination of terrestrial and extraterrestrial materials. The capturing and transferring of the gaseous samples by cryogenic means proved to be unreliable for the small quantities with which we had to work. Direct injection of the sample by means of a novel gas syringe has worked well. Retention times of mixtures of standard hydrocarbon gases (up to C_8) were determined for our experimental setup.

A survey of some different types of terrestrial rocks showed rather wide variation in the hydrocarbon gases evolved. This probably reflects the initial organic content, the thermal history, and the time exposure of the different samples. One young shale, however, showed marked variation in hydrocarbon gases from one-gram pieces adjacent to each other, reflecting the obvious heterogeneity of the organic fossil remains in the rock. An extensive survey of terrestrial rocks would probably have to be made before general statements can be made relating the hydrocarbon gases with the geological history of the rocks.

To date, we have examined four meteorites, (Orgueil, Murray, Cold Bokkeveld, and Mighei) and the results show methane/ethane ratios no greater than about 20, and most on the order of 5. We also detected the presence of ethane and propane and higher homologs in our samples.

These preliminary results were presented at the meeting of Carbonaceous Chondrite researchers at Ames Research Center in October.

Recently, we have extensively examined the problem of generation of hydrocarbon gases from the polymeric organic material of meteorites and sediments which comprises approximately 95% of their organic content. We now have data that indicates that the generation of light hydrocarbon gases by impaction is a minimal problem, and that the gases evolved are really trapped gases. We have also shown that by heating a sample to 300°C (after crushing) a very different suite of hydrocarbons evolved. These results are crucial to the experiments at hand. We intend to extend our analysis to other samples and to redo some of the meteorite samples.

Simultaneously, a second high-sensitivity GLC was constructed in our lab for non-destructive purification purposes.

ANALYSIS OF GEODETIC SATELLITE TRACKING DATA

NSR 05-007-060 (Kaula)

Analysis of Close Satellite Orbits to Determine Tesseral Harmonics of the Earth's Gravitational Field

W. M. Kaula

A new cycle of analysis was undertaken, increasing both the amount of data used and the number of gravitational harmonics

being determined. The number of satellites used was increased from 5 observed by camera tracking only to 7 by camera only; 1 by Doppler only; and 4 by both camera and Doppler tracking. The number of gravitational harmonic coefficients solved for was increased from 44 to about 90, sufficient to determine features of the gravity field more than about 2500 km in extent.

The principal difficulties in the work have been associated with developing and adapting computer programs to utilize Doppler tracking data, in particular accurate and efficient techniques to compress the data so that for repeated computer runs each pass could be represented by about 3 data points.

LUNAR ORBITER SELENODESY STUDIES

NSR 05-007-083 (Kaula)

Analysis of Lunar Orbiter Tracking Data

W. M. Kaula

Deep Space Information Facility (DSIF) tracking of the five Lunar Orbiter satellites is being analyzed to determine variations of the lunar gravitational field from the orbital perturbations. The program used for this analysis is characterized by a dynamical theory with an intermediary in terms of Keplerian elements which takes into account the long term variations arising from the earth and the main lunar terms. Shorter periodic variations are added analytically. Residuals are formed in terms of range and range-rate. The partial derivatives for the spherical harmonic coefficients of the gravity field are based on the assumption that their effects can be considered as forced linear oscillations about a secularly precessing intermediary. A least squares adjustment is made to determine the gravity coefficients and the orbital elements simultaneously.

The program was designed to require minimum modification from similar programs used for analysis of earth satellite orbits. However, progress has been slower than anticipated because of computation and debugging difficulties, many of them associated with system errors of the IBM 360/75.

Investigations of the Lunar Motion

W. M. Kaula, G. S. Benson

The lunar theory and observations of the motion of the moon were re-examined to determine why the moment-of-inertia of the moon deduced from the motion of the moon's node, $\dot{\Omega}$ was so unreasonably large: .64 for C/MR^2. It was concluded that the theory was correct, but that the "observed" motion of the node found by E. W. Brown in 1915 was in error. Brown deduced this motion as the difference between the motion in longitude and the rate-of-change in argument of latitude:

$$\dot{\Omega} = \dot{L} - \dot{F}$$

The observations of longitude used by Brown were over the period 1750-1910; of latitude, 1847-1901. Brown allowed for the secular acceleration and attributed the remaining irregular discrepancies between theory and observation as due to errors in the lunar theory. He thus in effect assumed the earth to be rotating uniformly (other than the secular deceleration). Since the reference time for the lunar longitudes was UT, the deduced motion of the node will be in error if the average rotation rate for 1750-1910 differs from the average rate for 1847-1901.

Assuming the irregular variations in O-C as due to the variations in rotation of the earth, a correction of -15".9/century in $\dot{\Omega}$ was obtained. This is more than enough to account for the discrepancy between the "hollow moon" found by Eckert and the value for a homogeneous moon. In fact, the new figure gives a central concentration somewhat more than the earth's: $C/MR^2 = .278$.

TIDAL THEORY AND ORBITAL PERTURBATIONS

NGR 05-007-138 (Kaula)

Ocean Tide Theory

W. M. Kaula, M. A. Joncich

The gravitational attraction arising from the ocean tide is about one-third to one-half that arising from the bodily tide, and hence should have a perceptible effect on satellite orbits, particularly on the phase lags. However, the theory of the ocean tides has never been adequately developed in a form suitable for use in calculating their perturbative effects on satellite orbits: i.e., in spherical harmonic coefficients. This lack

exists partly because a large-scale computer is needed for a meaningful solution and partly because the observational data heretofore pertinent have been coastal tide measurements.

The use of spherical harmonic coefficients also makes it convenient to take into account the elastic properties of the earth and the variations in ocean depth. The considerable algebra involved has been worked out, the computer programming has been done and debugging has been completed to the point of comparisons with previous solutions allowing for latitudinal variation in ocean depth (i.e., zonal coefficients $A_{\ell 0}$ (h) only) over a rigid earth (i.e. Love numbers k_2, h_2, k'_ℓ, h'_ℓ all zero). Runs allowing for the actual variations of the ocean topography and elastic yielding of the earth are being set up.

THE ABUNDANCE OF LEAD IN THE SUN

NGR 05-007-046 (Aller)

John Ross, Lawrence H. Aller, Orien C. Mohler

The nuclear stability of lead and its role as the end product of decay schemes of naturally occurring radioactive elements lends to this metal a peculiar importance in geochronology and cosmology. A datum of importance is the silicon/lead ratio. This ratio has been measured for chondrites and other meteorites. It is difficult to obtain a meaningful measurement for the earth because of the extreme fractionation suffered by terrestrial rocks.

Unless it has been affected by thermal and gravitational diffusion, the solar abundance of lead presumably represents the primordial solar system abundance. Unfortunately we cannot determine the solar isotope ratios by spectroscopic methods.

The difficulty in the determination of the solar lead abundance arises not so much from uncertainties in the transition probabilities of f-values, although these certainly stand in need of improvement, as in the character of the lines themselves. All solar spectral lines of lead fall in crowded regions of the near ultraviolet and are mostly heavily blended. Hence if one uses conventional methods he must estimate the intensity of the line, or more particularly the width in equivalent angstroms it would have if it were unblended. The trouble with this procedure is that it is sometimes difficult to make reliable allowances for blending effects.

We have adopted a procedure called "spectrum synthesis" in which one attempts to reproduce the detailed intensity distribution over the relevant wavelength region of the solar spectrum. In order to carry out this technique one must know:

(1) The wavelengths and identifications of all the lines in the region.

(2) The absolute intensity at some point in the spectral region.

(3) The accurate, i.e. high spectral resolution, intensity distribution over the spectral region involved.

In addition, one should know the limb darkening in the nearby continuous spectrum in order to obtain a check on the continuous absorption coefficient and its variation with depth in the sun.

Determination of Solar Abundances by Method of Spectrum Syntheses

John Ross, Lawrence H. Aller

A procedure was derived for obtaining the solar abundance, A, of an element, or more accurately gfA (where g is the statistical weight of the lower level and f is the oscillator strength). Instead of using the equivalent width of a line, one employs the entire profile. If the line falls in a crowded region of the spectrum where blending is severe, one attempts to reproduce the observed intensity distribution, $I_\lambda (0,\mu)$ over the relevant wave-length region, by including all relevant bound-bound transitions. The calculation has been programmed for an IBM 360/75 computer.

We assumed that when the parameters of the lines contributing to this region are adjusted so that the computed $I^\lambda (0,\mu)$ distribution matches the observed $I_\lambda (0,\mu)$ distribution the correct values of the parameter gfA has been obtained. The method is useful for those elements which are represented only by lines falling in crowded regions of the solar spectrum.

PHYSICAL SCIENCES RESEARCH SUPPORTED BY NsG 237-62

FUNDAMENTAL PROBLEMS IN ASTRONOMY

L. Aller

In this research project we are studying observational data on other stars and nebulae, using the 120-inch telescope at Lick Observatory. The data we have obtained thus far are spectrograms of stars of unusual chemical composition; spectrograms of rarefied gaseous nebulae, called planetary nebulae, associated with stars in the late stages of their evolution; and spectrograms of stars in late evolution stages, just before they evolve into so-called white dwarf stars having extremely high densities and shining by radiating away thermal energy of heavy particles.

Much of the data we obtain from our observations at Lick Observatory are used for research by our graduate students. However, high dispersion spectra, used for the analysis of chemical compositions of stars, must be obtained by a staff member; graduate students are not allowed to use the coudè spectrograph at Lick.

We have assessed and interpreted the spectra of a number of gaseous nebulae in terms of chemical compositions and physical conditions existing in these objects. The results were presented at the special symposium on planetary nebulae held in Czechoslovakia last summer.

By our use of and continuing improvements on model atmospheres, we are increasing the accuracy of our analyses of stars of unusual chemical compositions. Many of the methods and procedures we use also can be applied to the sun. In addition, we are working on the solar abundances of selected elements in connection with our NASA Grant NGR-05-007-046/Aller, the pilot work originating from our NASA subgrant.

24-INCH TELESCOPE FOR PLANETARY AND STELLAR OBSERVATIONS

L. Aller

Using the 24-inch telescope now installed at an Ojai site, we have developed a small efficient facility for photometric and spectroscopic observations of stars, nebulae and planets. The telescope is used not only as an instrument to train students and to develop skills with which to build new equipment, but also for serious research programs pertinent to fundamental questions about the properties of stars--the relation between spectral color and character on the one hand, and between luminosity,

mass, evolutionary state and chemical composition, on the other. We are paying particular attention to stars in binary systems because they provide basic data on stellar sizes and masses. In addition, we are observing weird and unusual properties such as variable magnetic fields, unusual chemical compositions, etc.

There has been considerable delay in our research because of the extremely poor quality of the spectrograph. Rather than return the instrument to its builders, Dr. Epps has refigured the optics and improved certain mechanical features so that the spectrograph now functions near its theoretical performing limit. A photoelectric photometer also has been built and is now operating.

The spectrograph and photometer are being used for a study of a variety of problems including:

(1) Photometry of magnetic stars: Certain stars whose surface temperatures are in the neighborhood of 10,000-12,000°K have magnetic fields whose phases often vary with changes in the spectrum and light. Mr. J. Oliver is carefully measuring these light variations and he hopes to correlate them with magnetic and spectrum changes.

(2) Eclipsing binaries: Double stars so close to one another in space and so aligned that they eclipse one another as they move about in their orbits provide fundamental data on the sizes and masses of stars, and we observe a number of these objects through the 24-inch telescope. Professor D. Popper is obtaining eclipse data for stars observed spectroscopically with the 120-inch telescope at Lick Observatory, and Mr. J. Montgomery is carrying out photometric studies of these data.

(3) Photometric studies of the spectra give clues to the luminosity and temperatures of stars because the appearance of the star's spectrum depends both on its temperature and on its surface gravity. These clues, of course, are useful in studying stellar evolution and Mr. M. Dworetsky, under Professor Upton's supervision, is collecting spectrograms for these studies.

(4) Spectral classification of the hottest stars known, the O stars, is being undertaken by Miss Heap. In addition, there are some routine tasks that have to be undertaken. These include determination of atmospheric extinction and obtaining standard plates and spectral classification.

New Supplementary Equipment In Service

1. Stellar Spectrograph

A stellar spectrograph, funded by the Chancellor's Office, UCLA, was purchased for approximately $15,000 from Astro-Mechanics, Inc., Austin, Texas, in June, 1966. This spectrograph did not meet specifications and was found to be completely unserviceable as it was delivered. Since we had already waited one year for the spectrograph, we decided that the instrument could be put in service sooner if we rebuilt it ourselves, rather than sending it back to Astro-Mechanics, Inc. Rebuilding continued through the fall and the spectrograph was finally fitted to the telescope and put in service during December, 1966. The instrument is capable of recording stellar spectra in the dispersion range between 50 Å/mm and 250 Å/mm. It can be used to a faint limit of 10th magnitude at maximum dispersion and 13th magnitude at minimum dispersion. To date, approximately 500 stellar spectra have been obtained with this spectrograph. It is now working at or near its theoretical limiting efficiency and resolution.

2. Photometer

A wide band photoelectric photometer was designed and constructed at UCLA and fitted to the telescope in January, 1967. With various interchangeable combinations of filters and photomultipliers, this instrument allows one to do UBV, six color, or interference filter photometry. The unique 3 mirror Cassegran design of the 24-inch telescope allows an observer to switch from photometry to spectroscopy in approximately 15 seconds, making the spectrograph and photometer an ideal pair of instruments for the study of rapid time variations in moderately bright stars.

New Supplementary Equipment Being Designed

1. Photoelectric Scanner

Design work on a low resolution scanning spectrophotometer has been in progress since February, 1967. This instrument will be interchangeable with the photometer on the west fork of the 24-inch mounting and will be usable in conjunction with the spectrograph as described above. This combination is particularly useful for accurate spectrographic calibration purposes. It is hoped that the instrument will be in service by June, 1968.

2. Nebular Camera

Design of an extremely fast Schmidt Camera was begun in May, 1967. This camera, at f/0.6, will enable the stellar spectrograph to be used on extended sources such as nebulae and external galaxies. Since the faint limit of a nebular spectrograph is independent of telescope aperture, the addition of the camera will enable some research currently being done at the 120-inch telescope of the Lick Observatory to be carried out at the Ojai Field Station.

3. Image Tube Camera

During April, 1967, the Department of Astronomy was promised a Carnegie Image Tube to be delivered in 1968. Funding for the construction of an image tube camera was secured in June, 1967. This camera will be used in conjunction with the stellar spectrograph and it is estimated that the faint limit of the instrument will be increased two magnitudes or more. This will increase the number of stars accessible to the 24-inch spectrograph by a factor of 10 or more and enable spectra to be taken of the Scorpio x-ray source, 3C-273, and other unusual objects of current astrophysical interest. Design of the image tube camera will be started during the winter of 1967.

New Support Facilities

During May, 1967, an optical laboratory was started by the Department of Astronomy, using equipment funds provided by the Chancellor's Office and space provided by the Department of Engineering. An optical technician, Mr. Richard E. Brandt, joined the Astronomy Department staff on June 1, 1967.

The prime function of the optical laboratory will be to aid in the development and construction of the image tube camera mentioned in the section above. A secondary function of the optical laboratory will be to contribute toward the development of other supplementary instrumentation for graduate student and faculty research programs at the 24-inch telescope and at the Lick Observatory. In addition, the optical laboratory will be used for the purpose of teaching practical astronomical optics in the UCLA graduate Astronomy program.

The establishment of this laboratory is considered by the Department to be the most important single advancement in the development of observational astronomy at UCLA to date. Its maintenance and growth is considered indispensable to the growth of the Department of Astronomy in both teaching and research.

Current Research

Included below is a list of the research programs currently being carried out at the Ojai Field Station by the faculty and graduate students of the Department of Astronomy in both teaching and research at UCLA (faculty names are underlined).

1. Time variations in the spectra of Wolf-Rayet stars. L. F. Smith.

2. Spectroscopic determination of the Balmer Discontinuity in early-type stars. E. K. L. Upton and M. Dworetsky.

3. An investigation of atmospheric extinction (including azimuthal variation) at the Ojai Field Station. H. W. Epps and D. McCarroll.

4. Light variations in metallic-line stars. J. P. Oliver.

5. Determination of the apsidal motion of several eclipsing binary systems. H. W. Epps and D. McCarroll. H. W. Epps and J. Montgomery.

6. Photometry of eclipsing binary systems whose spectra have been obtained at the 120-inch telescope. D. M. Popper.

7. Photoelectric and spectrographic observations of Nova Delphinus 1967. E.K.L. Upton, H. W. Epps, J. Oliver, J. Montgomery, and M. Dworetsky.

Summary

The 24-inch telescope at the Ojai Field Station is primarily a teaching instrument of small aperture. However, the supplementary equipment which has been added during the period July 1, 1966 to June 30, 1967 has enabled the staff and graduate students here to undertake serious research projects, some of which are underway and are listed above. Prior to the establishment of the Ojai Field Station, the staff was limited to the facilities of the Lick Observatory, while the graduate students were essentially unable to conduct observational research prior to starting thesis work.

While the 24-inch telescope can never compete with the superior light-gathering ability of the 120-inch telescope at Lick Observatory, it can provide observations to be used in conjunction with the 120-inch telescope data, provided it is equipped with appropriate supplementary equipment. In addition, the use by graduate students of the 24-inch telescope and its supplementary equipment will help to insure the most effective

use of larger telescopes by these students when the opportunity arises. In view of the scarcity of large telescopes, the importance of the latter point cannot be overemphasized.

MAGNETICALLY SHIELDED TEST FACILITY

P. J. Coleman, Jr. and J. D. Barry

This project is concerned with the development of a laboratory facility with an environment sufficiently free of magnetic noise to allow testing and calibration of relatively sensitive magnetometers. The facility consists primarily of a magnetically shielded room which provides the working volume with comparatively little magnetic noise. The volume contains an environmental chamber and a triaxial Helmholtz coil array which are used to test the response of magnetometer probes at various temperatures.

Since March, 1967, the facility was improved by the addition of some auxiliary test equipment. The major item of additional equipment is a high-field coil that will be used in studies of the magnetic properties of materials in general and spacecraft hardware in particular.

Also, we are planning for a series of experiments to determine the physiological importance of the ambient magnetic field in collaboration with Dr. Robert Pogrund of the Department of Health Sciences. In an earlier phase of this program, we designed a triaxial array of Helmholtz coils and control system similar to those used in our facility. We installed the coil system and operators were trained by Mr. J. D. Barry of our group. Pilot experiments were then run using these coils to increase the magnetic field in the space occupied by test rats. Auxiliary equipment required for the follow-on experiments in our magnetically shielded facility is presently being developed.

In applying the planned experiments we intend to explore the relationship of the ambient magnetic field to biorhythmic elements in human ecology and to cardiovascular and cardiopulmonary dysfunction. Over the longer term the research will be extended to include studies of human response to VHF electromagnetic stimulus.

A paper entitled "A Magnetically Shielded Chamber Used in Simulating Space Environment" was presented at the Symposium on Space Magnetic Exploration and Technology at the University of Nevada, Reno, August 28-30, 1967, and is to be published in the Proceedings of the Symposium.

ROCKET PROJECT

P. J. Coleman, Jr., U. Fehr, B. Ben-Ary

This project is devoted to the experimental study of very low-frequency acoustic and electromagnetic disturbances in the atmosphere and ionosphere. To date, our efforts have been concentrated on the study of naturally occurring and man-made atmospheric disturbances with frequencies below the audio range, that is, with frequencies below 20 Hz. Acoustic waves in this ultra-low frequency range are called infrasonic waves. Our work here has been concerned primarily with disturbances in the frequency range from 0.05 to 20 Hz. This upper end of the infrasonic range was selected because man-made sources of noise at these frequencies are readily available. At the same time, many natural phenomena produce disturbances in this frequency range. The waves at these frequencies are primarily acoustic in nature, whereas at the lower frequency, longer wavelength end of the infrasonic spectrum, the waves are strongly affected by the earth's gravity. These longer waves are more properly called acoustic-gravity waves. A major problem in the study of the higher-frequency end of the infrasonic spectrum is that measurements of disturbances at these frequencies are complicated by the effects of winds.

The work has progressed in three fairly well defined phases, two of which have already been completed. The first phase included the development in the laboratory of sensitive pressure sensors and wind attenuators and the subsequent development of an integrated system of such devices for use in the field. The system is composed of an array of sensors and recording equipment to permit simultaneous measurements at a number of locations in the field. The second phase included the measurement of disturbances from man-made sources. The specific disturbances studied were those produced by rocket engine igniters, and rocket engine exhausts. Measurements were made during both static firings and actual rocket flights. During static firings, the data were taken with an array of sensors located at various positions surrounding the static test stand. During rocket flights, the data were taken with an array of sensors located at various surface positions around the launch pad and along the surface projection of the flight path. Most of the work performed in these two phases has been reported in the literature. The remainder will be reported shortly.

The third phase of the research was undertaken in March 1967. The immediate goal of this phase is the study of the coupling between atmospheric pressure variations and ocean waves with periods between one second and forty seconds. In our experiments, infrasonic measurements were taken on San Nicolas

Island and ocean wave height measurements were taken simultaneously in the ocean surrounding the island. We selected San Nicolas Island because the ocean around it is fairly representative of deep sea conditions, since the island is far enough from land so that reflections of water waves from the mainland are not significant. The infrasonic sensors were arrayed on the island shores that are in the path of the prevailing ocean waves. Anemometers were also positioned at the locations of the infrasonic sensors. An ocean wave height sensor was set at a deep sea location some distance from the island. A set of five tests during simultaneous measurements was taken with all of these instruments and has been completed. We are presently reducing the recorded data.

During the spring and summer 1967, we have also undertaken the fourth phase of the program. In this phase it is intended to launch a series of rocket payloads composed of explosives in various quantities. The explosives will be detonated at selected altitudes and the resulting disturbances will be recorded with several types of instruments at a number of surface locations on board an earth satellite above the location of the explosion. This phase of our work is concerned with the study of the propagation of these disturbances in both the ionosphere and atmosphere. Of specific interest are the characteristics of the high altitude cutoff for infrasonic propagation, and the characteristics of the coupling of acoustic and magnetohydrodynamic waves in the ionosphere and at the boundary between the ionosphere and the atmosphere. The results may also bear upon the processes responsible for Whistler generation and the propagation of electrostatic waves in the lower atmosphere.

The planned flights include three to 50-km altitude with a payload of 150-pound TNT equivalency; two or three flights to 100 km with a payload of 300 pounds of TNT equivalency; and a few flights to the altitude of the ionospheric F-1 layer with payloads of 1000 pounds TNT equivalency.

During these tests, data will be taken with infrasonic sensors at ground level below the site of the explosion and at several, more distant, surface locations with ionograms probing the ionosphere near the area of the explosion, and with magnetometers and electric field detectors at various surface positions and at satellite altitudes.

Personnel at Vandenberg Air Force Base will perform the ionospheric sounding. The Navy at the Pacific Missile Range will provide the rockets, explosive payloads, telemetry from the array of sensors, experiment coordination, and facilities for data reduction. These experiments were planned in collaboration with personnel at TRW, Aerospace Douglas, Lockheed, LTV, and Space

Engineering. The analysis of the data from this series will be performed in collaboration with Dr. F. L. Scarf, and Mr. Gaines Crook from TRW, and Drs. MacPherson and Blake from Aerospace.

A feasibility test was conducted on June 14, 1967, with positive results. With the successful completion of this feasibility test, the participation of UCLA personnel in this project was terminated. Our research in this area has yielded the instrumentation and the preliminary results necessary for the undertaking of a relatively major effort in experimental geophysics. The support in terms of personnel, equipment, and facilities to be provided by the Navy at the Pacific Missle Range and by the Air Force at Vandenberg Air Force Base will make it possible to complete the mission scheduled for the fourth phase of this research without further support under this grant.

Students participating in this research project and receiving partial support are U. Fehr, who received his Ph.D. Degree in September, 1966; J. D. Barry, B. Ben-Ary, Miriam Cohen of the Math Department, and Samual Raz in the Department of Public Health.

CHEMISTRY AND SPECTROSCOPY UNDER HIGH FIELD OF THE GIANT LASER BEAM

M. A. El-Sayed

Our studies are concentrated on the following subjects which have created much attention and interest in the dispute to settle the problems:

Study of Zeeman Effect on Polyatomic Molecules under High Pulsed Magnetic Field

Zeeman effects on atoms have been studied extensively, but as yet, molecular Zeeman effects have not received extensive study. Zeeman splitting in molecules would provide much information about the energy levels of molecules. A vast field remains to be explored with the high magnetic field and to settle such problems we have started the following experiments.

We have assembled six condensers each of 200 mf capacity at 4 KV, meeting the requirements of (i) short, closely spaced low inductance leads, and (ii) strong energy of high voltage and low capacity with the resulting short time constant. For the discharge of the condensers, a spark gap system has been developed. It has a dual set of adjustable clamped brass

electrodes and is triggered by a third electrode connected to an automatic ignition coil when 300 V pulse is supplied to the primary windings of the output pulse transformer.

We are making Helmholtz coils for the magnet out of hardened berylco - 25. Making coils from a flat strip of hardened berylco posed a great deal of technical difficulty, so attempts are being made to make the coils from the solid rod by cutting deep rectangular helix.

Double Photon Absorption in Pyrazine

First observations of two photon absorption by two red ruby photons in anthracene crystals has created much interest and attention about the nature of transition and the type of excited states involved. It was suggested that (1) an electronic state of even parity or (2) vibronic state of even parity existed in the region of photon energies of twice the ruby laser photon energy, based on the assumption that the observed effect was due to a second order dipolar transition. It was also proposed that the effect was caused by the (AA) interaction term of the Hamiltonian. Only careful and thoughtful experiments would settle this problem. Pyrazine has an extremely weak system of sharp bands in the region 3760-3560Å and a moderately strong system of sharp bands in the region 330-2900Å. Therefore, we have launched our investigations on pyrazine with our giant ruby laser system, with the expectation of exciting a state corresponding to photon energy twice the ruby laser photons.

We have fabricated an optical system consisting of a 10-100 megawatt laser source, a photocell to measure the intensity of exciting laser light, a second photocell to measure the fluorescence light, and a dewar to house the sample at liquid nitrogen temperature. The outputs from the photocells after amplification are fed into the input terminals of a Tektronix 1A1 pre-amplifier which is used in the Tektronix 531 oscilloscope.

We have performed some preliminary experiments with anthracene to measure the incident laser light and that of fluorescence light. We repeated the experiments with anthracene to enable standardization of the present optical system. With pyrazine, we will attempt to see whether a fluorescence which would vary as the square of the excitation intensity could be produced by means of the intense laser beam.

ASYMPTOTIC MOTION OF MASS PARTICLES IN THE SOLAR SYSTEM

J. Kane

There is a substantial interface barrier between the digital computer and its application to the equations of celestial mechanics, the laws being differental relations, and the computer best suited for arithmetic operations, in particular, the transferring of integers from storage position to storage position--integer permutation. During the past period we have been successful in "digitizing" the equations of celestial mechanics, arriving at a format ideally suited for the computer, and we have programmed a simulated solar system such that planetary perturbations are modeled by integer permutation.

The problem we have considered is one relevent to the origin of planets according to the accretion theory: Imagine an ensemble of particles--say 10^{10} golf balls--to be sprinkled throughout the solar system, with random positions and velocity, at some initial epoch, time t=0. Considering all planetary perturbations, where will they accumulate, and in what densities, after an astronomically significant time period, say 10^{8} years?

Our basic idea exploits the fact that planetary perturbations are cyclical in nature, constantly repeating. Properly compounded, the knowledge of planetary perturbations for one fundamental period gives the temporal behavior of the system for all time, in much the same way that the spatial behavior of solids in bulk can be gleaned from knowledge of a basic microscopic crystal.

For purposes of our algebraic formulation, it is convenient to think of the solar system as a bounded six dimensional box in configuration space, the variables being the orbital elements, position and velocity, or any suitable set of generalized coordinates. For convenience, we have restricted our attention to the plane of the ecliptic, reducing the dimensionality from six to four. Each point within this four dimensional box defines the motion of a mass particle within the solar system. By choosing a limit of accuracy, say one part in ten thousand, the configuration space can be partitioned into 10^{12} hypercubes, higher resolution requiring finer quantization and increased storage space within the computer.

Each hypercube in this quantized space can be put into one-one correspondence with the integers, and the flow field in the configuration space defines a certain permutation law. In other words, by this process, differential calculus is simulated by

block transfer. Represent this transfer operation by Δ (for displacement). Δ is done very rapidly in the computer and represents the shift of position of the mass ensemble after a fundamental time period, say t seconds, and n-fold iteration of the displacement operator $\Delta,^n$ gives the motion after nt seconds. While any iteration takes an extremely short time in the computer (on the order of microseconds), compounding them arithmetically to calculate time periods of the order of 10^8 years would seem prohibitive. But the iterations can be compounded exponentially, since Δ^n is itself a permutation. For example, once Δ^2 has been calculated, iterate Δ^2 obtaining Δ^4; another iteration gives us Δ^8, and so on. In other words, by iterating multiplicatively we go up by powers of two; after n such iterations we have Δ^{2n} corresponding to a time projection of t^{2n} seconds. Not only is such machine calculation fast--on the order of minutes--but it must also be mentioned that such "digitized dynamics" is absoultely stable, there being no round off error in the calculus of integer transfer.

We have completed programming a simplified model of the solar system. Normally, the storage capacity is of the order of 50K, but by an indexing scheme devised by John Rouse, we are able to simulate a solar system consisting of 2^{31} hypercubes, approximately 10^{12}. In other words, we can resolve the asymptotic distribution of particles within the solar system to an accuracy of one part in 10^3. With further advances in computer technology, this should improve substantially.

We have also completed programming on-line output in the form of computer graphics. Following a delay caused by machine difficulties (imperfection in IBM's "G level" compiler) we are beginning production runs. We expect to have final output, and reports for distribution shortly.

CYCLING OF ELEMENTS IN BIOSPHERE, HYDROSPHERE AND ATMOSPHERE AND THE CHEMICAL EVOLUTION OF LIFE EVOLUTION

I. Kaplan

Studies of the cycling of elements in nature are continuing in our laboratory. Results are being obtained using the techniques of trace element analysis, stable isotope measurements, and identification of light hydrocarbon gases by gas chromatography. Support from NASA to conduct these studies has enabled us to purchase necessary equipment and to establish a Biogeochemistry Laboratory.

Our project, initiated by this subgrant support, will continue under new contracts and grants awarded from NASA, ONR, ACS and AEC.

STUDIES OF THE COMPOSITION OF THE SOLAR WIND

W. F. Libby, D. Lal, S. Aegerter

Project Laundry Bag - The plan to collect samples of the solar wind with an Echo-type balloon in highly elliptical orbits is being developed on three different fronts. The first is the improvement of our understanding of the mechanism of trapping plasma impinging on aluminum and other materials. This work is being conducted at the Tata Institute in Bombay by Dr. Devendra Lal and Dr. S. Aegerter and at UCLA and the Oak Ridge National Laboratory.

Oak Ridge bombards various solid surfaces with kilovolt beams of plasma of various kinds and the retention efficiency and reevolution on heating characteristics are measured in Bombay. Dr Aegerter will come to Los Angeles in January of 1968.

The second part of the project is the preparation of ultra-pure aluminum by the distillation of aluminum alkyls, and the subsequent thermal decomposition to form aluminum. We test the purified aluminum alkyls by neutron activation in the UCLA reactor. The impurities which could be detected by this technique are those of interest since it is our intent to analyze the solar wind samples in the same way for everything except hydrogen and helium. The indications are that this procedure should be successful.

The third part of the present effort on the project is an attempt to assess the concentration of interplanetary dust which might contaminate our solar wind samples (the dust particles sticking to the Laundry Bag surface). We are testing to determine whether the aluminum 26 which Lal and Wasson separately found in sea sediments and attributed to the in fall of cosmic ray irradiated dust did not have an alternative source. Recent evidence from other lines of investigation such as J. R. Arnold's ballon-borne dust sampler indicates that the amount of dust in interplanetary space may be considerably smaller than earlier estimates. The aluminum 26 isotope which is made easily by primary cosmic rays impinging on almost any meteoritic matter labels interplanetary dust clearly. Therefore, when aluminum 26 was found in the sea sediments Wasson and Lal separately interpreted this as evidence for something like 1,000 tons of dust per day falling into the earth. Such an influx probably would correspond to a confusing amount of interplanetary dust in the space around the earth (which would be sampled by the Laundry Bag).

An alternative explanation of the aluminum 26 in sea sediments is that the cosmic ray μ mesons which impinge on the earth's surface could produce the aluminum 26 in silicate minerals and that erosion of the continents accounts for the radioactivity of aluminum 26 and the sea sediment. An attempt, therefore, is being made to obtain several tons of surface quartz which has been on the earth's surface for hopefully a million years or so (since the radioactive life time of aluminum 26 is one million years), and to analyze this for aluminum 26. In this procedure the quartz is dissolved in hydrofluoric acid and the solution is evaporated. This completely vaporizes the quartz and leaves most of the impurities as residue since they are non-volatile. This residue will contain the radioactive aluminum 26 mixed with any ordinary aluminum present as impurity. Separation of the aluminum from this residue and purifying it will allow the measurement of its radioactive concentration of aluminum 26 to be made. This task has been undertaken jointly by Associate Professor Russell Honea of the Geology Department of the University of Colorado at Boulder and by the Research Institute of the Colorado School of Mines, in Golden, and the group at UCLA. Dr. Aegerter will join us to help with the counting work.

It seems likely that if our present calculations on aluminum 26 from negative μ meson capture by silicon are correct, the Laundry Bag project may be cleared of the interplanetary dust hazard.

An incidental benefit of tne surface quartz work quite possibly may be a new method of dating surface rock exposure and erosion rates.

ANALYSIS OF CARBON COMPOUNDS IN CARBONACEOUS CHONDRITES

W. F. Libby

Some additional meteorite samples have been acquired through purchases: for instance, the Faucett meteorite of four pieces totaling 95 pounds. The Group for the Analysis of Carbonaceous Chondrites has added to material for its use a number of small samples of the important carbonaceous chondrites and one or two rather substantial non-carbonaceous samples.

PLASMA STUDIES

L. Wood, F. T. Aldridge, R. C. Davis, J. Jensen, W. F. Libby

Our efforts are directed toward understanding the interactions of intense electromagnetic fields with a variety of gases heated to such temperatures that they become ionized and constitute relatively good conductors of electric currents; matter in such states constitutes virtually all of the physical universe. The sun, the interplanetary medium and the upper portions of the earth's atmosphere are examples of this plasma state of matter. Time-varying electromagnetic fields exert pressure in a flossy fashion on such conducting gases, somewhat similarly to a skein of taut rubber bands being forced through a mass of viscous material, such as jello. These fields thus may be employed both to contain and manipulate plasmas and (necessarily) to transfer energy to them without having any material object coming into contact with them; both the containment pressures and the energy transfer rates are extremely high in the work we are doing. Our studies apply to a variety of research areas of considerable current interest which range from a more complete understanding of the light emissions of stars to the problems involved in controlling thermonuclear fusion processes.

In the period since August, 1967, we have made significant progress toward our goal of transferring energy to plasmas at peak rates in excess of one megawatt, and continous transferral rates of several hundred kilowatts. We have continued our exploration of relatively dense high temperature ($P \approx 10^3$-10^6 dynes cm^{-2}; Te~1-5 ev) plasma of various compositions at the ten kilowatt power level, and have continued the high-power testing and trouble-shooting of our megawatt electrodeless plasma generator. We have also very substantially extended our DC magnetic field generator capabilities in connection with other work described below, and have gained in ability to manipulate and control plasmas.

INTENSE SHORT WAVELENGTH LIGHT SOURCES

L. Wood, R. C. Davis, C. A. Jensen, F. G. Potter, A. F. Bernhardt, W. F. Libby

Our studies are oriented toward the production of very intense light sources in the ultraviolet and far ultraviolet portions of the spectrum for use in several research programs. These programs are concerned primarily with the basic physics and

chemistry of energetic light's interaction with matter, particularly in the gaseous phase. Such research is, of course, important to many of the space sciences, because the sun is an intense source of such chemically potent radiations, and everything in space--e.g. satellites and planetary probes, space suits and planetary atmospheres--is necessarily exposed to it. Because such radiation is so chemically active, it is absorbed by and only reacts with the uppermost portions of planetary atmospheres and does not, in most cases, penetrate to planetary surfaces, the Moon being, of course, a notable exception.

Our studies, aided by the 584Å light emitted from a helium plasma source we developed, indicate that the particularly intense radiations emitted from the newly-born sun in the solar system's early history were quite likely to have photochemically polymerized, and therefore destroyed, several of the major components of the chemically reducing atmospheres thought to have been previously present over most planets (including Earth). Although they destroyed the atmospheres, the radiations coincidentally provided many of the raw materials needed for the origin of life. At present we are developing even more intense light sources to facilitate our analyses of results. We are also trying to produce sources of different wavelength; sources currently in use are the most intense continuously operating monochromatic ones known, and we are studying the interactions of varieties of light produced with simulated planetary atmospheres of various compositions and under conditions approximating those actually found in nature.

We also are continuing to work on the development of continuous high efficiency lasers in the near ultraviolet. Continuation of the theoretical studies mentioned in our last report has proved encouraging, and fabrication of the necessary experimental equipment is nearly completed.

HIGH MAGNEITC FIELDS PROJECT

L. Wood, C. A. Jensen, W. F. Libby

Our efforts are concentrated on the development of rapidly variable sources of high magnetic fields and, thus with the fabrication and use of conventional solenoids, because the preferred, negligibly dissipating superconducting solenoids are not satisfactory for this use at present. Such fields have been found to be very useful in controlling and directing plasmas and, as mentioned in previous reports, in generating intense light sources by stimulating the production of electron synchrotron radiation.

Work is continuing also on developing effective low-cost techniques for fabricating high performance superconducting links.

SATELLITE DATA ANALYSIS AND SOLAR-TERRESTRIAL RELATIONS

L. Wood, L. D. Howard, W. F. Libby

We are still analyzing data from the first Orbiting Solar Observatory (OSO-1), and are doing extensive filtering and processing to remove spurious information from these data. We continue to correlate our analyses with information derived from sinultaneous groundbased observation and we have noted a number of features of the solar-terrestrial interaction that either were previously unknown or only conjectured. Our findings will be submitted to the literature.

In conjunction with other projects, the theory of the motion of matter in the Earth-Moon system is being studied extensively, with emphasis being placed on the nature of the recently discovered Dust Moons at the dynamically stable Lagrangian points located on the lunar orbit at two vertices of an equilateral triangle whose third vertex is near the center of the Earth. We have discovered that mass apparently cannot be contained in these regions over geophysically significant time periods. These regions thus cannot constitute a museum of the history of the Earth-Moon system (as had been previously suggested) principally because of the non-zero eccentricity of the moon's orbit about the Earth; the mean residence time of mass passing through such regions is about the order of a few lunar orbital periods (i.e., a few months). We are investigating the effects of solar wind perturbations, light pressure and gravitation self-stabilization of these apparently ephemeral Dust Moons. With the aid of high-speed digital computers, we are delving into other potential museums of solar system history, such as the corresponding regions in the orbits of Jupiter and Saturn, as part of a general program of investigations of mass motion in the solar system.

MEASUREMENTS OF SKY BRIGHTNESS AND POLARIZATION DURING THE TOTAL SOLAR ECLIPSE OF 12th NOVEMBER 1966

C. R. Nagaraja Rao, Z. Sekera

We are attempting to evaluate quantitatively the role of secondary and higher order scattering in defining the ambient radiation field in a planetary atmosphere. Such an evaluation realtes not only to present attempts to understand the contrast transmission properties of the earth's atmosphere, but also to

understanding the physical processes governing the transfer of electromagnetic radiation in inhomogeneous and spherical atmospheres.

It is best that such investigations be conducted during a total solar eclipse, when, during totality, the primary source of the dominant contribution due to primary scattering--the sun--is removed from the shadow zone. We have successfully completed a program of multicolor measurements of skylight polarization at a point 90°00' from the sun in the principal plane of the sun and a study of variations in relative brightness during the total solar eclipse of 12 November 1966, in collaboration with Mr. James G. Moore of U. S. Naval Ordnance Test Station, China Lake, California.

A rotating analyzer-type variable gain photopolarimeter (UCLA) and a simple filter photometer (U.S. NOTS) were designed and built for these investigations. We received logistic support from the Sandia Corporation, Albuquerque, New Mexico. Mr. Moore performed both the polarization and sky brightness measurements.

Practice eclipse runs were made in and around Kirtland Air Force Base, Albuquerque, N. M., until November 2, 1966, when the aircraft flew to Buenos Aires, Argentina, the base of operations for the eclipse expedition. On November 12, 1966, the aircraft intercepted the shadow of the moon at the point 49°39'W, 34°28'S at an altitude of 33,500 ft. The path of the central line of total phase and the region of interception are shown in Figure 1.

Data were recorded on multichannel FM-FM analog magnetic tape recorders; auxiliary multichannel oscillographic recorders served as quick-look facilities. The results of the polarization measurements obtained from an analysis of stripchart data are shown in Figure 2. The variation of the degree of polarization during the eclipse is representative of what our theories predicted and resembles what was observed during the total solar eclipse of May 30, 1965. The differences between the two sets of measurements must be explained in terms of different circumstances of the two eclipses such as, for example, the presence or absence of cloud decks below the aircraft, the lack of flatness and the size of the shadow, the solar elevation, etc. We will attempt such an explanation after computing the eclipse function for a uniform solar disk. We plan to present the results of the present series of measurements at the forthcoming solar eclipse symposium tentatively scheduled to be held in Brazil in February, 1968.

We used a portion of our allotted funds to complete analysis of the data obtained during the 1965 eclipse. Our results are presented in a paper entitled "Observations of the

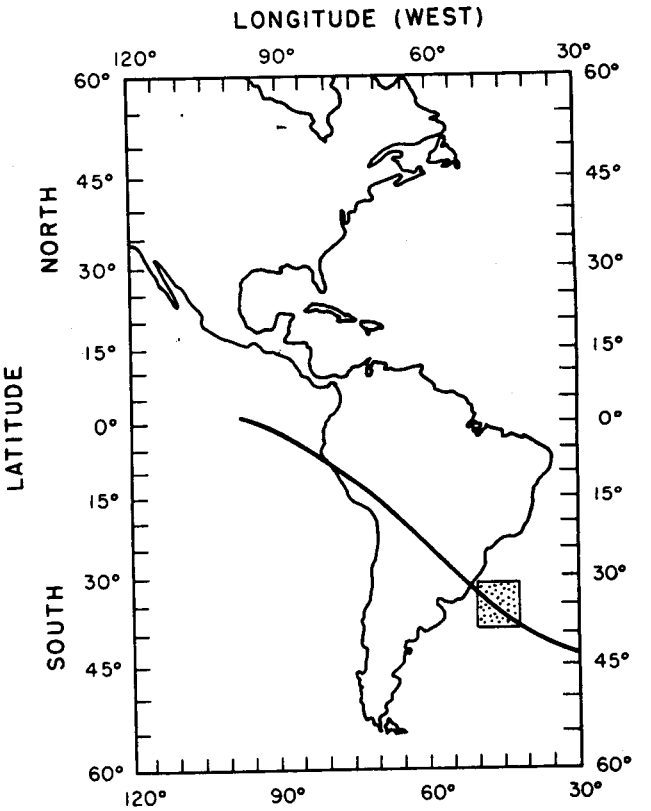

FIG. 1. CENTRAL LINE OF TOTAL PHASE OF SOLAR ECLIPSE OF 11/12/66 STIPPLED AREA DENOTES REGION OF INTERCEPTION

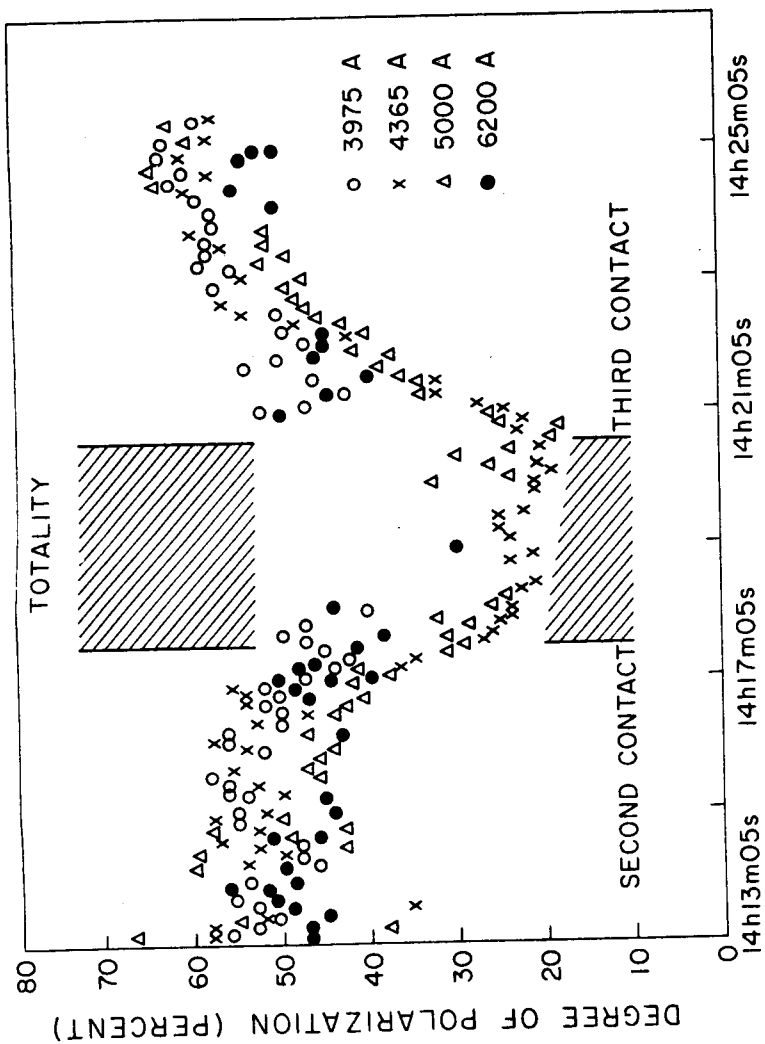

Fig. 2. Measured values of polarization (11-12-1966).

Day Airflow During the Total Solar Eclipse of 30 May 1965," which will appear in Annales de Geophysique. Hsi-She Chen, a graduate student who was partially supported by these funds, was awarded the M.A. degree in Meteorology for his thesis entitled "Investigations of the Polarization of Light Reflected by Natural Surfaces."

Professors Balmont and Vassy (University of Paris), Professor Newell (MIT), Dr. Nordberg (NASA) and Dr. Liebenberg (NSF) have evinced keen interest in the research we are performing.

SYNOPTIC STUDY OF THE IONOSPHERE DURING THE QUIET SUN PERIOD

S. V. Venkateswaran

This is the initial phase of our study on the motions and morphology of ionospheric regions. Using about 40,000 ionograms recorded by the ionospheric satellite, Alouette I, during the period 1962-64, we have reduced and constructed pole-to-pole cross-sections of the topside ionosphere on a day-to-day basis. A prominent feature of these cross-sections is the "equational anomaly." By studying this feature in great detail, we now have a satisfactory picture of the diurnal development of the anomaly and its longitudinal and seasonal dependence. In addition, we are studying the storm effects on the anomaly.

About 200 station years of conventional (ground-based) ionosonde data were used in a study of tidal effects in the ionosphere both during a period of maximum solar activity (IGY-IGC) and during a period of minimum solar activity (IQSY). We believe that this study is more comprehensive than any previously attempted, and provides a starting point for further work in ionospheric dynamics.

Graduate student C. M. Rush, participating in this project, completed his Ph.D. degree in June, 1967.

ATOMIC ABSORPTION SPECTROMETER II

J. Wasson

In our laboratory, we use the Perkin-Elmer 303 spectrometer to determine nickel concentrations in iron meteorites and also for three meteorite research projects involving neutron activations. Neutron activation is used to determine the amount of gallium in iron meteorites. Following radiochemical isolation and counting gallium, we measure carrier recovery by atomic

absorption spectrometry. We are analyzing indium in petrologic suites of chondritic meteorites in a similar fashion, with carrier recovery being measured by atomic absorption. Finally, we are studying molybdenum concentration in meteorites of all classes by neutron activation, and the carrier yield is determined by atomic absorption spectrometry.

The funding for research on the composition meteorites has been transferred largely to NSF Grant GP-5309.

BIOLOGICAL SCIENCES

MONITORING BRAIN FUNCTIONS AND PERFORMANCE IN THE PRIMATE UNDER PROLONGED WEIGHTLESSNESS

NAS 2-2503 (Adey/French)

W.R. Adey and J.D. French

Preparations for the 30 day Biosatellite experiment have reached an advanced stage. The Space Biology Laboratory serves as coordinator of those aspects of the experiment contributed by the University of Southern California, the University of California at Berkeley and Jet Propulsion Laboratory, and Texas Women's University, as well as contributing to the UCLA experiment on central nervous functions and biological rhythms. In November, 1967, Dr. Robert Schiffman relinquished his post as project director to accept an appointment at the University of Missouri. He has been suceeded by Mr. Pierre Hahn, who has been closely associated with the Biosatellite project as a staff member of NASA Ames Research Center.

In October-November, 1967, a comprehensive simulation of the Biosatellite flight was performed at UCLA, including count-down, flight and recovery phases. The test was performed in an actual spacecraft, provided by the General Electric Company and supported by GE engineering staff. In the aggregate, the test was most successful, providing excellent baseline data on physiology and performance capability. The primate remained in good condition for a total restraint period of 45 days, including 30 days in the flight capsule. Neurological and cardiovascular instrumentation performed in a highly satisfactory fashion. Problems were encountered with clogging of the urine transport line with calcareous debris. Careful investigations since the test have indicated that this phenomenon relates to alkalinity of the urine. Revised protocols will attempt to mitigate this problem, by modifications in diet and strict asepsis in attachment of the primate to the urine transport line during capsule insertion.

Analysis of neurophsiological data from this test is now nearing completion. Circadian rhythms were modified but well sustained through the 30-day period. Computer analysis of EEG data indicates modified states of attention in the later phases of the test. Extensive spectral analyses of the circadian components in EEG, EKG and temperature data have indicated important harmonics in the major rhythm process.

Plans are proceeding for a second such test at UCLA beginning early in April. The launch date is scheduled for late 1968. A major improvement in primate preparation in task performance has been effected by introduction of "errorless" training methods, first developed in the University of Washington. These methods have allowed training of the primate to a 90 per cent criterion in the delayed-matching-to-sample task in two to three weeks, compared with three months by conventional methods.

A STUDY OF BRAIN FUNCTIONS THROUGH ADVANCED COMPUTER TECHNIQUES FOR ANALYSIS OF EEG DATA

NsG 505 (French/Adey)

J.D. French and W.R. Adey

The development of computer control during actual experiments in the Space Biology Laboratory allows monkey and chimpanzee behavioral testing in a series of contingency learning tasks, and a study of physiological concomitants of psychic stress in man, with on-line evaluation of the physiological parameters including calculation of complex parameters in the EEG, such as coherence in cross-spectral analysis. The remote console system which allows time-sharing of the computer by five investigators is being connected with the SDS Computer, and when completed will enable the experiments to be run from the investigator's laboratory with on-line computer evaluation of data.

From this experience, it is proposed to develop a computer-based physiological monitoring system suitable for on-line monitoring of pilot status in the aerospace environment. To this end, pattern recognition techniques have been applied to EEG and other data, based on step-wise discriminant analysis. Preliminary applications have shown that this method has over 90 per cent accuracy in assessment of basic states of consciousness from 10 second epochs of data. Dr. J. Hanley has recently applied these pattern recognition techniques to EEG parameters from chimpanzees playing tick-tack-toe, and has completed a study which separates with 100 per cent accuracy the EEG patterns in performing and non-performing states, and between correct and incorrect decision making epochs. Plans are proceeding under supervision of Dr. D.O. Walter and Dr. W.R. Adey for more sophisticated pattern recognition techniques, involving multivariate spectral analysis whereby three or more channels of

EEG are analyzed simultaneously in order to elucidate generator distribution. A program is being developed aimed at drawing out of EEG data parameters that parallel or define a behavioral state, such as learning, habituation and in broader states of consciousness, such as recovery from drugs and decompression sickness. This program, like the discriminant analysis program developed in this laboratory, is treated as a guide to a more focused pursuit of a problem rather than as an absolute index of a state. These techniques are being refined and modified to apply to studies in the Laboratory involving up to 1,600 different physiological measures.

The availability of the Time-Data Corporation convolution integral computer, the TD-100, has given us the capability to use two new computing techniques. One involves the Tukey complex demodulation technique, which aids greatly in extracting primary and secondary characters from records covering a broad spectrum. The other involves spectral averaging, a technique that makes sequential spectral analyses at short time intervals in an advancing record and averages them. It thus obviates many problems of "smearing" where single analyses are made over long epochs. Both metnods are suited to on-line analysis.

The SDS Computer has been widely used in the digitization and plotting of electroencephalographic data from several studies in the Laboratory, including data from a program of research on learning in monkeys subjected to severance of various commissures between the cerebral hemispheres. Spectral analysis was applied to digitized data in a study on the effect of body position on tne EEG output from different subcortical and rhinencephalic structures. Also, a study on the neurophsiological correlates of learning in chimpanzees is being brought under computer control, whereby a series of contingency learning tasks are delivered to the animal, and the EEG records are analyzed in an on-line fashion for possible immediate modification in the experiment. The SDS Computer has also been used in the study of the phsyiological concomitants of psychic stress in man. A question sequence is delivered to the subjects by means of videotape, and on-line computer evaluation of various EEG and autonomic parameters and the responses to the questions permits modification of the subsequent questions.

NEUROPHYSIOLOGICAL AND BEHAVIORAL STUDIES OF CHIMPANZEES
NsG 502 (French/Adey)

J.D. French, W.R. Adey

This study of the learning and discriminative behavior of chimpanzees under Dr. J. McNew is based on a test apparatus designed and built in the Laboratory which provides incremental learning opportunities, as well as the testing of short term memory. The apparatus is computer-controlled and a program has been written to conform to the on-line capabilities of the Space Biology Laboratory Computer facility. This system permits the investigator to define performance criteria, prepare the entire strategy of the experiment, pass control to his setup and reacquire control whenever desired for modification, delay or other intervention. The program provides six phases in the presentation of learning tasks to the chimpanzee, bringing the animal up to the performance level required by the last phase of the experiment--being able to discriminate between 12 symbols and match correctly to those symbols presented in varying numbers and order. Six chimpanzees have undergone surgery for implanting brain electrodes, and three animals are receiving behavioral training on the learning device.

In addition to the study of the electrophysiological correlates of learning and behavior, a normative library is being collected of central nervous, cardiovascular, and autonomic nervous functions before, during and after learning. This comprehensive library will eventually be used to provide baseline information for flight studies on the long-term effects of weightlessness on physiological functions. This comprehensive data will be vitally important in extrapolation to planned manned flights. The sleep-wake patterns of the chimpanzees are being evaluated while the animals are free-moving in their colony housing environment, using biotelemetry of EEG data from cortical and subcortical electrodes. This allows the recording of more natural sleep-wake patterns than usually are acquired from restrained animals, and also permits study of group interaction effects of EEG patterns. Several of the chimpanzees have been trained to wear a 4-channel telemetry pack developed in this Laboratory strapped to the back, and the remainder of the animals are being trained to do so. In addition to EEG data, the investigators are monitoring the electrooculogram, neck and trunk electromyogram, galvanic skin response, brain temperature, intracranial pressure and electrical impedance of cerebral tissue.

The normative library of cardiovascular information is presently being enlarged by deriving electrocardiogram data from

an impedance pneumogram which enables the experimenter to obtain qualitative information on ectopic beats and bundle conduction characteristics. Additional cardiovascular monitoring will be incorporated with the development of DC flowmeter probes being investigated in this laboratory.

Baseline data on endocrine system functioning is also being collected. This program is undertaking an extensive study under Dr. A. Mandell of the excretions of 17-hydroxysteroids, catecholamines and/or catecholamine metabolite VMA, calcium, phosphorus, creatine, creastinine, and ADH, as well as the daily urine output in the growing chimpanzees. Comparison of these data with that acquired during actual space flight will produce valuable information on the effects of weightlessness on the functioning of the endocrine system of the chimpanzee.

CONTINUING BASIC PROGRAM IN SPACE BIOLOGY

AF 49(638)-1387 (French/Adey)

J.D. French, W.R. Adey

Studies in the past year have pursued a strong theme that related basic biomedical investigations in biochemical, neurophysiological and cardiovascular parameters to problems of manned aerospace flight. Baseline information is provided by these studies, against which potential changes in space flight might be assessed.

Fundamental cerebral mechanisms are being studied by Mr. R.T. Kado, in particular the integration of the afferent projections in the cerebellar cortex, the area of the brain dynamically involved in the implementation of changes in position of the limbs and trunk as well as the execution of finely graded placing maneuvers. These experiments involve the development of a technique for recording electrophysiological data using very fine wires chronically implanted in animals, allowing acquisition of data from active animals performing simple but intricate tasks requiring highly coordinated movements.

The program includes a study of the actions of various spontaneous (wakefulness and sleep) and drug-induced states (hallucinatory, epileptoid and anesthetics) on the activity of neuronal units in the midbrain reticular formation. In addition, Drs. W. Winters and C. Spooner have begun a new study on the effects of fatty acids on the electrical activity of the brain and on behavior. Data suggest that butyric and decanoic acids,

and other convulsant agents, induce epileptoid activity in the EEG by virtue of an impairment of glucose utilization presumably at the level of pyruvate metabolism. Intravenous and intraperitoneal injections of low doses of gamma-hydroxybutyrate, gamma-butyrolactone, or the fatty acids failed to induce a state of paradoxical sleep. These investigators are also studying the maturation of the blood-brain barrier in the growing chick, concentrating on the uptake of tritium-labeled biogenic amines and their precursors, norepinephrine (NE), dihydroxyphenylalanine (DOPA), 5-hydroxytryptophan, H^3 dopamine, and H^3 serotonin. Drs. Spooner and Winters are working on the isolation and measurement of a soluble protein, termed S-100, specific to the neuroglia of the nervous system.

The role of amine and steroid metabolism in psychophysiological stress are also being studied. Implication of these substances as direct mediators of excitation of nerve cells in brain tissue has become clearer from structural and functional studies. In addition to behaving as transmitter substances, Dr. Mandell's studies suggest an important role of amine substances as constituents in mucopolysaccharides that form surface coats for nerve cells, and exercise a controlling function in excitation through interaction with divalent cations, and in particular with calcium ions. Changes in calcium metabolism have been clearly implicated in current space flights, and it appears that modest changes in brain calcium levels are associated with marked changes in excitability.

In a study by Dr. R. Berger of eye movement patterns in monkeys raised from birth without patterned vision, results reveal a progressive decrease with maturation in the rate of eye movement during low voltage fast wave sleep in both the normal, sighted, control animals and the pattern-deprived animals, although the rate of this decrease appears to be greater in the pattern-deprived animals than the controls. A special analog device constructed in the Laboratory measures velocity of eye movement, and application of this device has shown velocity of eye movement during both wakefulness and low voltage fast wave sleep to be slowed in the pattern-deprived monkeys compared with the controls. The cytoarchitecture and cell morphology of the visual systems in these pattern-deprived and normal sighted monkeys has been studied, revealing no differences in the fine structure of the cortex between the two groups.

Dr. Berger has also undertaken a study of eye movements during paradoxical sleep in monkeys that have been conditioned to differential rates of eye movements during wakefulness. The technique developed has proven successful, and the animals were conditioned to move their eyes at differential rates. Results to date indicate that conditioned rates of waking eye movement

generalized to rapid-eye-movement (REM) sleep in the following manner: the rate of REM and total number of REMs were higher during longer REM sleep periods following low rates of waking eye movement, than following high rates, while similar effects were absent in the yoked control animal. It is hypothesized from these results that REM sleep furnishes periodic innervation of the oculomotor system to maintain facilitation of binocularly-coordinated eye movement into subsequent wakefulness.

In conjunction with these neurophysiological and environmental studies, the Laboratory is pursuing the development of various flight bioinstrumentation devices including a DC blood flow transducer. Mr. J. Zweizing and Mr. Kado are experimenting with implant materials that are impermeable to water yet also slightly flexible. A related project is underway with Dr. J. Riddle using two such flowmeters to measure dynamic properties of flow in relation to the conduit system. Large flowmeters have been constructed and preliminary measurements made. The results of the study will have implications for design problems relating to value configurations in artificial hearts, and in defining haemodynamic properties of blood.

Efforts are also being devoted to the packaging and miniaturization of a multichannel biotelemetry system. This system will be used in the Laboratory's program on the neurophysiological and behavioral study of chimpanzees; recordings will be taken during learning to assess changes in the EEG. A telemetry unit to fit the crown of an implanted monkey's head has been built and used in 24-hour recording sessions. Work has also progressed on the development of single channel telemetry units mounted on the electrode connectors on the animal's head; as many as three of these have been used simultaneously during a 24-hour period with the animal in his normal living quarters.

New instrumentation has been devised by Mr. Kado and Mr. J. Kater for sensing and amplifying the EEG from the scalp of performing man. The method involves a bathing cap that is readily put on and taken off by the user, and a new type of non-polarizable electrode that incorporates a preamplifier. These studies are being undertaken with a contract from the Manned Spacecraft Center, Houston. It is a study aimed at evaluating cycles of sleep and wakefulness, and levels of attention in task performance, in the course of 28 and 56 missions in the Apollo Applications Program.

SUMMER INSTITUTE IN SPACE BIOLOGY

NSR 05-007-089 (French/Adey)

J.D. French, W.R. Adey

The Space Biology Laboratory conducted its second Summer Institute in Space Biology this year. The program is for junior and senior undergraduate students selected on a national basis from applicants with backgrounds in the life and physical sciences. The Institute is a recognition of the urgent need for highly skilled investigators in the many areas that lie within the realm of space biology, and is an effort to interest young people in the prospect of a research career in one of the fascinating and significant areas of environmental biology and bioengineering. The course is designed to give the students a broad background in pertinent problems of mammalian physiology. The Institute included lectures by teaching faculty drawn from NASA Ames Research Center, the University of Southern California and the Harbor General Hospital, as well as from a number of departments in the UCLA School of Medicine. The curriculum provided a survey of problems in exobiology, followed by a brief survey of physiological functions liable to modification in the space environment, including effects of weightlessness on cardiovascular and renal reflexes and on body fluid distribution; the effects of weightlessness and confinement on metabolic functions, with particular reference to skeletal muscular disturbances; and modifications of characteristic cyclic mechanisms in sleep, body temperature control and endocrine functions. Central nervous system functions were also discussed in relation to the stresses of acceleration and vibration, the effects of weightlessness on visual and vestibular components of motor performance, and the possible effects of the space environment on psychic functions. The special problems of experimental investigation in the space environment were considered in recoverable and nonrecoverable experiments, and included discussion of command and control programming, data acquisition and recording systems, telemetry and equipment reliability, and how these are related to the physiological problems being studied. Ames Research Center provided material on exobiology and consideration of the origins of life, methods of detection of living systems, adaptation of organisms to exotic environments, and biotechnology.

The program included a series of tours to give the students a first hand glance at the existing programs and facilities.

The tours went to Douglas Missile and Space Systems Division, North American Aviation, University of Southern California, Ames

Research Center, and the Jet Propulsion Laboratory.

The Institute was considered a great success by the student body, and a third program is planned for the summer of 1968.

ELECTROENCEPHALOGRAPHIC AND OTHER PHYSIOLOGICAL INDICATORS OF SHORT-TERM STRESS

NONR 233 (91) (Adey)

W.R. Adey

The Laboratory is engaged in a program aimed at evaluating the physiological concomitants of stress, using both autonomic and electroencephalographic measures. The experimental paradigm developed by Dr. J. Berkhout, which consists in the presentation of a neutral and stressful question sequence during recording of EEG and autonomic parameters, has been carried out on a group of volunteers. This experiment established the dynamics of autonomic responses, and provided valuable information on the differential autonomic activity between subjects and between questions. These autonomic data showed that the galvanic skin response (GSR), measures used in standard interrogation tests, to be unrelated to the specific content of particular questions and answers, whereas circulation parameters are related. Specifically, changes in heart rate appeared to be primarily associated with the presentation of questions, while changes in finger pulse volume were primarily associated with the production of answers. In general, the results indicate that several types of responses are found which characterize given individuals, and that autonomic responses to hearing a question may be distinguished from responses contingent on producing an answer.

Analysis of EEG data from the study indicates the value of the EEG as a measure that should be included in standard interrogation procedures. Its greatest advantage over autonomic indices of stress is in temporal resolution. Whereas GSR responses are ballistic over several seconds, and circulatory phenomena are defined only once per heartbeat, EEG activity may be evaluated on a fractional second basis, and thus more closely related to specific times in the interrogation process. While this study does not reveal any observed EEG patterns that can be generalized over a large population, it does demonstrate that many useful conclusions about the stress reaction patterns of specific subjects may be drawn from their EEG data: and it should be noted that universally applicable criteria are not

necessary for the type of differential stress detection called for in the screening situation.

A new experiment is being designed, making use of a video tape recorder for the question sequence presentation, which will be valuable in lending added credibility to the "live" nature of the experiments, as well as assure uniformity and consistency of the stimuli from subject to subject. The protocol has been designed to make use of the on-line computing capabilities of the SDS 930 Computer. The physiological responses to a sequence of questions will be evaluated by computer as the experiment is proceeding; the question sequence will then be repeated, with several of the questions objectively selected by discriminant analysis of the first set of responses as showing the greatest "stress" in the context of the individual's overall response picture. A secondary "follow-up" set of questions available on the video tape will then be presented, and the responses to these questions independently evaluated. This method will provide a good illustration of the value of on-line computing capability as an essential component in evaluation of short-term psychological stress.

These studies in suddenly imposed, short-term psychological stress simulate many aspects of conditions encountered by pilots and astronauts in evaluating and responding verbally to changing environments in aircraft and spacecraft. Such a fine-grained analysis of human responses in these environments, based on simple physiological parameters, is a much-needed baseline.

EEG CONCOMITANTS OF EXPOSURE TO OSCILLATING ENVIRONMENTAL ELECTRIC FIELDS

ARPA DADA 17-67-C-7124 (Adey/Kado/Walter)

W.R. Adey, R.T. Kado, D.O. Walter

Varying gravitational fields have been shown to have an effect on human behavior, in particular reaction time performance. This phenomenon therefore becomes an extremely important consideration in manned space flight. Hence, in this program, the electroencephalographic concomitants of exposure to low voltage frequency electric fields is being investigated, in humans and animals. One study has been completed by Mr. J. Hamer, involving student volunteers in which their reaction times were taken over a period of several days, sometimes in the presence of a weak electric field of not more than 2.0 volts.

The data indicate that low level, low frequency electric fields can affect human reaction time performance, and these results are being substantiated. A similar experiment is in progress, with time interval estimation by the subject as the experimental end points; preliminary results show effects on subjective estimates of elapsed time to be well above the reaction time effects in magnitude.

In conjunction with Mr. Hamer, Drs. J. McElligott and R. Gavalas are transferring the experimental approach to animals. Using monkeys with implanted brain electrodes, this phase of the study is concerned with finding neurophysiological correlates for the shifts in reaction times produced by the field. A suitable behavioral paradigm is being established that will permit a very sensitive measurement of response times. The experimental paradigm being developed is compatible with the on-line data acquisition and analysis capabilities of the Space Biology Laboratory Computer facility and the new Time Data Corporation TD-100 Computer, which will perform spectral analysis of data as the experiment is proceeding. The capabilities of the Laboratory have been greatly expanded as the result of the addition of the new TD-100 convolution integral computer to the SDS 930 computer. Dr. Walter is developing the exact protocol for analysis for the behavioral paradigm established.

BIOLOGICAL SCIENCES RESEARCH SUPPORTED BY NsG 237-62

PROGRAM TO ASSESS BASIC PHENOMENA UNDERLYING BEHAVIORAL ASPECTS OF COMPLEX LIVING SYSTEMS IN SPACE

J.D. French and W.R. Adey

The bioscience program, relating to the known and anticipated effects of the space environment on mammalian organisms, covers a broad gamut from molecular biology to the phenomena in complexly organized systems, such as the central nervous, renal, pulmonary and cardiovascular. Studies in these systems most frequently have as their basis a consideration of physiological substrates at cellular and subcellular levels. It is here that interactions with subtle environmental factors, such as modified gravitational and magnetic fields inherent in exposure to space will exert their effects. Hence, this program aims at elucidating the processes occurring at these levels.

Drs. Spooner, Mandell and Winters are investigating in the growing chick the appearance of the blood-brain barrier; the changes with age in brain phospholipids, proteins and extracellular fluid space; uptake, metabolism and role of biogenic amines in the regulation of sleep-wakefulness, motor activity and vocalization; the action of antidepressant drugs on these amines; and the effects of various amino acid loads on behavior. Investigators are developing gas chromatographic micromethods for study of the amines and their metabolites, and thin layer chromatographic techniques are being applied to isolate isotopically labelled metabolites from brain tissue.

The Laboratory continues to improve techniques of tissue preservation is electron microscopy, as well as pursue research in the ultranstructure of brain tissue. Dr. Adey and Mr. H. Wang, in conjunction with the electron microscopist, Mrs. B.G. Bystrom, have perfused brain tissue with inert substances (including certain silicone compounds) with the aim of preserving the living tissue without destroying its water structures, an important aspect of tissue organization. Research is also in progress to determine the state of the cell membrane at various levels of calcium concentration; particular attention is paid to the mucopolysaccharide cell coat which is the basis of excitability changes, and to the extracellular space.

In the application of the techniques developed in physical optics to the study of biological tissue, Dr. H. Lyons is investigating the biochemical changes in intact brain tissue using fluorescence spectroscopy. Tissue spectroscopy involves spectroscopic identification and measurement of molecular compounds on whole tissue, rather than after separation and purification of the compounds. This permits studies of the concentration of particular compounds as a function of other biological correlates in the natural environment of the cell, making possible more realistic and accurate correlations with concomitant EEG data, or neuropharmacological, behavior and surgical experiments. An initial group of experiments is underway on the resolution of individual components of known mixture (e.g., of rare earth chelates). We hope eventually to apply the method to identification of biological molecules in brain tissue. A high resolution monochromator is used to eliminate the effects of light scattering in the sample. Two sets of curves are measured: the fluorescence spectrum for a range of fixed excitation wavelengths, and the temporal excitation curve for a range of fixed fluorescence wavelengths. The complete families of curves thus obtained are sensitive measures of the concentration and environment of the molecular species present. In preliminary studies, the fluorescence of brain tissue in cats, rats and avian species has been measured, with evidence of spectral signatures in widely different segments

of the visible spectrum.

The electrophysiological correlates of various behavioral states also are being investigated. Dr. A. Costin and Dr. Adey are studying the influence of body position on subcortical and rhinencephalic EEG in the cat. In addition, the effects of surgical section of the vestibular nerve and the dorsal column of the spinal cord, and various afferent stimulations are being evaluated.

Another electrophysiological study concerns the correlates of learning in a series of monkeys ranging from those with intact brain structures, to those in which surgical intervention has served an increasing number of commissures connecting the two brain hemispheres. Preliminary results indicate almost complete transfer of learning in the normal animal on a 2-choice visual discrimination task performed with one eye and the contralateral paw, while the monkey with an optic chiasm cut showed considerable transfer of learning, and the split brain monkeys show no transfer of learning. While the results obtained on these animals are being analyzed and confirmed, a new study is being designed to evaluate evoked responses in the same animals.

Dr. A.T.K. Cockett is pursuing studies on the effects of environmentally induced cardiovascular and respiratory-circulatory changes on the kidneys and lungs. These have included the investigation of the physiology of decompression sickness, the effects of increased gravity, on rats in the area of renin concentrations in kidney tissue after centrifugation, and a program evaluating the fructose, citrate and lactic acid in the ejaculate from Nemestrina monkeys as related to changed environmental conditions.

NEW CONCEPTS IN STRUCTURAL DESIGN

NsG-423 (Shanley)

F. R. Shanley

The current research project is orientated primarily along two basic lines. The first is the fabrication of prestressed shells formed of ceramic segments, and the second is the investigation of integrally stiffened "waffle" type structures.

In addition, the theories and procedures previously developed for component optimization are being used in a continuing study of optimization of structural systems.

Theoretical and experimental studies are being carried out in the following areas.

1. Prestressed Ceramic Dome

Work is continuing on the study of the feasibility of constructing prestressed ceramic shell structures. A prestressed spherical dome formed of small flat triangular plastic segments has been constructed as a preliminary step in this study.

Current effort is devoted to the construction of a similar dome formed of small flat triangular ceramic segments. Suitable molds from which the ceramic segments will be formed are under construction. Advantage will be taken of current and previous related research in the ceramic area.

Preliminary steps are being taken to develop high-temperature high-strength cables for use in the prestressed ceramic shells. Texaco Experiment Incorporated has voluntarily expressed a willingness to attempt fabrication of cables from silicon-carbide filaments for this purpose.

2. Prestressed Ceramic Plate

Tests have been performed to determine the bending and twisting rigidity properties of a hexagonal prestressed ceramic plate fabricated of 1350 equiangular triangular ceramic elements. The agreement between test results and analytic predictions was good.

Approximate analytic values for D_I, Poission's rigidity constant, will be checked in future experiments. A "whipple tree" loading fixture is being constructed to allow antielastic bending.

3. Composite Materials

Several small specimens of a composite material have been fabricated. The composite consists of glass fibers and microspheres in an epon matrix.

Difficulties in achieving a homogeneous mixture of matrix, fibers, and spheres have been encountered. Various curing methods have been tried and have led to a more homogeneous mixture than originally achieved. In addition, recent work has shown that wrapping the spheres with the fibers results in a more homogeneous mixture; however, the improvement is dependent on the size of the spheres. Attention will be devoted to determining this relation between sphere size and the degree of homogeneity.

4. Integrally Stiffened "Waffle" Structures

Several rectangular "waffle" plates having stiffeners orientated in three directions have been constructed and tested under uniaxial compression. The plates and the stiffeners were fabricated from polyvinyl chloride plastic.

In addition, plates having secondary stiffeners, for which spacing is greater than that of the primary stiffeners, will be constructed and tested shortly. The purpose of these secondary stiffeners is to prevent instability over larger wavelengths.

Experimental data from all tests will be correlated with analytically predicted behavior.

5. System Optimization

Work is continuing on the use of mathematical programming techniques in structural design. The general design problem was formulated using the displacement method of structural analysis. The specific example of truss design was considered in detail. Component optimization was introduced into the truss design by allowing the critical components to fail simultaneously by both Euler and local buckling.

BSD (RTD) BALLISTIC MISSILE RETARGETING STUDY

AF 04 (694)-826 (Leondes)

C. T. Leondes, E. B. Stear, A. R. Stubberud

Development of Algorithms for Advanced ICBM Reference Trajectory Determination

Sequential Optimization of ICBM Trajectories (D. Isaacs, R.Niemann)--Both algorithms for determining ICBM reference trajectories have been running on the IBM 7094 digital computer. The most recent studies on the computer have involved simulation of a real time in flight determination of ICBM reference trajectories using these algorithms. The calculations have been very successful, and it appears that these algorithms provide effective methods for explicit advanced ICBM guidance.

Algorithms for Variable Flight Time ICBM Trajectories (R.Niemann, G.Paine)--The sequential optimization techniques developed in this program have included techniques for determining the time of flight as part of the ICBM reference trajectory determination. Studies are also being carried out to determine if more computationally efficient techniques for flight-time determination can be evolved.

Reference Trajecotry Determination Optimized With Respect to C.E.P. (E. Volgenau)--The object of this study was to develop a systematic means for developing ballistic missile reference trajectories in a way that will improve missile accuracy.

A number of computer runs have been made, using two different hypothetical boosters, a large, two-stage liquid ICBM and a smaller three-stage solid ICBM. Results showed a sigificant improvement in missile accuracy over that achieved when a minimum energy trajectory is used.

Advanced ICBM Re-entry Vehicle Techniques

This phase of the program is concerned with determination of techniques for advanced ICBM re-entry vehicles of either the multiple warhead type or the advanced maneuvering re-entry vehicle class, or other classes of advanced ICBM re-entry vehicles.

Work is nearing completion on optimum design and linear guidance law formulation of entry vehicles for guidance parameters and temperature accumulation along optimum entry trajectories.

ICBM Control Law Development

Efforts in recent months in this area of research have started to yield some rather fundamental and apparently important results in relation to suboptimal ICBM control law development (G.Kang) and adaptive control of a two-point boundary problem for advanced ICBM control using sensitivity functions (J.Watson).

Filtering Techniques in Advanced Ballistic Missile Guidance and Control

Nonlinear filtering techniques avoid the necessity of carrying out linearizations and result in the ultimate in system performance. The potential importance of results J.R. Fisher has obtained in this area could be applied in a number of ways to advanced ICBM performance and control.

Maximization of the Attainable Region for a Maneuvering Re-entry Vehicle

For a given set of re-entry initial conditions, a control function is to be determined which allows achievement of the largest possible range of landing sites without exceeding the imposed restrictions at any time during its flight. Consideration must be given to use of three-dimensional dynamic equations of flight for atmospheric re-entry and maneuvering with state variable constraints, including a minimum allowable velocity, maximum heat accumulation, and an acceleration bound so as not to exceed structural capabilities.

Multilevel Trajectory Optimization

Multilevel optimization as applied to ballistic and space systems appears to be a systematic way to attack a very complex problem by decomposing both the trajectory (time) and the system (state equations), solving these smaller problems and iteratively combining the results to reach the final solution.

ENGINEERING RESEARCH SUPPORTED BY NsG 237-62

OPPOSED-JET DIFFUSION FLAME AS A TOOL FOR CHEMICAL KINETICS STUDIES

C. Chu

We have found the opposed-jet diffusion flame extremely useful for studying high temperature kinetics. The flame forms between two opposed coaxial jets, one containing a fuel and the other an oxidant. Since the fuel and oxidant are separated, the diffusion flame aids in those cases where, were the reactants premixed, the burning velocity would be too high and the flame zone thickness too narrow to be studied accurately.

Work is concentrated on the diffusion flame's thermal structure, using a 0.001" diameter Pt-Pt-Rh thermocouple coated with S_1C_2. A micromanipulator capable of measuring distances accurately in three mutually perpendicular directions to within 0.01 cm. pinpoints the thermocouple's location within the flame, which results in a three-dimensional temperature distribution. This temperature distribution has, in turn, resulted in a useful quantitative measure of the apparent flame strength.

Our future work will include further determination of the flame's thermal structure using various fuel-oxidant combinations, and chromatographic analysis of the combustion products.

N. K. Patel, a Ph.D. candidate, has been supported by this research. His field of interest is "Opposed-Jet Diffusion Flame."

TWO ASPECTS OF THE INFLUENCE OF DISSOLVED HYDROGEN ON THE BEHAVIOR OF IRON AND STEEL

A. Flanigan

This work investigates the effect of higher aging temperatures on the phenomenon of hydrogen-induced strain aging in iron (i.e., on the tendency of specimens to exhibit hydrogen-induced discontinuous yielding during subsequent straining). In particular, we hoped to learn if there existed a critical aging temperature above which hydrogen-induced strain aging would not occur. The existence of such a temperature was to be expected since hydrogen-induced strain aging is believed to be related to

the strain aging which, under suitable conditions, can be induced when either carbon or nitrogen is present in iron; the latter effects have been reported to occur only when aging is carried out at temperatures below approximately 330°C. The determination of a similar limiting temperature for hydrogen-induced strain aging, if it could be accomplished, might be expected to furnish an interesting clue concerning the magnitude of the interaction energy for hydrogen and dislocations.

We were unable to demonstrate the existence of such a limiting temperature for hydrogen-induced strain aging. The significance of the failure is obscured, however, by experimental difficulties arising from the presence of small amounts of carbon and nitrogen in the specimens. To distinguish hydrogen-induced strain aging from the similar (but stronger and more sluggish) effects which are exerted by carbon and nitrogen, it is necessary to use suitable low aging temperatures. Hydrogen-induced strain-aging was identified after aging at temperatures as high as 90°C; however, at higher temperatures, the larger aging effects attributable to carbon and nitrogen developed so rapidly that it was not possible to distinguish the separate effects, if any, associated with hydrogen.

In the second portion of the work, we sought to determine the manner in which the characteristics of hydrogen-induced discontinuous yielding (after suitable strain aging) would be affected by variations in the temperature and rate of straining.

This aim was suggested by an observation of Rogers, who had reported that, under the conditions of his own work, hydrogen-induced discontinuous yielding did not occur at straining temperatures above -78°C. In particular, we hoped to determine the influence of strain rate on the magnitude of the maxinum permissible straining temperature (i.e., to determine the influence of strain rate on the magnitude of the temperature above which hydrogen-induced discontinuous yeilding would not occur).

It was found that each increase in strain rate produced a corresponding increase in the value of the critical temperature. Such a dependence suggests that, for any particular straining temperature, there is an associated strain rate below which moving dislocations are unable to break away from their atmospheres of hydrogen. Presumably the diffusion of hydrogen permits atmospheres to keep pace with moving dislocations, so long as the strain-rate is not too great at a given temperature. Perhaps this observation furnishes another clue to the mechanism of the industrially important phenomenon of dynamic hydrogen embrittlement in iron.

The research work reported here was done by James Kaae, as an extension of an earlier study which served as the basis for Dr. Kaae's Ph.D. dissertation.

LOW DENSITY GAS DYNAMICS AND MOMENT METHOD IN RAREFIED GAS DYNAMICS

C. Y. Liu

The investigation of rarefied gas dynamics bears direct consequence to vehicles traveling in planetary atmospheres. It is generally accepted, with regard to such mean quantities as temperature and pressure, that a detailed knowledge of the velocity distribution functions for a gas is relatively unimportant. This assumption has instigated our search for a modified moment method. We applied the modified Lees' moment method to the problem of plane Poiseuille flow and researched low speed flow over a sphere. Currently we are studying the hypersonic flow problem of rarefied gas over a sphere and the preliminary results are encouraging.

One interesting phenomenon uncovered in solving boundary value problems in rarefied gas dynamics is the procedure of "matching" solutions. Kubota's study of head conduction from a fine wire finds that the complete solution can be obtained by "matching" a collision-free solution valid near the body to a collision-dominant solution valid at large distances from the body, both these studies being based on the argument that the heat transfer (or drag) computed by the "inner" solution should be the same as that given by the "outer" solution. We have found this "matching" procedure applicable to the following simple problems, the results of which have been submitted for publication:

(a) linear couette flow

(b) rarefied gas flow between two rotating cylinders

(c) low speed flow over a cylinder

(d) low speed flow over a sphere

(e) flow over a finite flat plate

These applications show that Kubota's finding is certainly not restricted to one single case and we are now examining its usefulness in solving non-linear problems. Most importantly, our "matching" procedure is the first step toward formulating a systematical method to obtain an asymptotic solution to the

Boltzmann equation. Cercignani has begun preliminary study on the linearized Boltzmann equation and our efforts will be directed toward the extension of the "matching" procedure.

We have submitted a proposal entitled "Moment Method in Rarefied Gas Dynamics" to the NSF for further support. Our present NASA grant has supported the following students: T. Sugimura, Ph.D. candidate in Engineering (in progress) and Richard Passameneck, M.S. student in Engineering (degree awarded).

DETERMINATION OF THE KNOOP-HARDNESS OF TUNGSTEN SINGLE CRYSTALS

J. P. Neumann

The ever-increasing demands for materials with high strength at elevated temperatures have made the refractory metals, and in particular, tungsten, a primary target of investigation. Although a number of technical alloys have been developed, a satisfactory understanding of the mechanical behavior of tungsten and its alloys is still lacking. In this project, we are attempting to use microhardness measurements to determine the dislocation mobility in tungsten single crystals at cryogenic and elevated temperatures.

Our study has a twofold purpose of (1) determining whether Knoop-hardness tests can be used to define the mode of deformation of tungsten single crystals having different crystallographic orientations when tested at different temperatures, and (2) determining whether Knoop-hardness tests can reveal work hardening in tungsten single crystals.

The crystallographic orientations selected were the (110) and (012) planes. We chose these planes so as to maximize the resolved shear stress on [112] and [110] planes respectively. Test temperatures covered the range from 77° to 1073°K. The effect of the elastic recovery of the impression produced during the test was considered quantitatively in order to determine the true hardness number.

Our results indicate that when Knoop-hardness tests were performed on a surface paralled to the (110) plane, deformation occurred by slip on [110] <111> systems at 77°K. When testing the (110) plane at 203°, 296°, and 1073°K, slip occurred on [111] <111> systems. While not detectable at 77°, 203°, 296°K, work hardening was revealed at 1,073°K.

More high-temperature measurements on tungsten single crystals will be conducted within the following months, in

cooperation with Dr. L. Raymond of Aerospace Corporation. We will seek future support for a continuation of this program by extending it to tungsten alloy systems.

M. Tarkanian received his Master's degree in June, 1967, basing his thesis on work from this project.

Dr. Gordon Bentle of the Atomics International Division of North American Avaiation, Inc., arranged for and aided in the use of the hot hardness tester. Consent for the use of this equipment by the U.S. Atomic Energy Commission is appreciated.

IRRADIATION STRENGTHENING OF TITANIUM AND ITS ALLOYS

K. Ono

With the aim of improving the sheet welds of cryogen containers and other aerospace structures, we are studying the basic properties of point defects in titanium and its alloys. We are particularly interested in the hardening effect of point defects produced by electron irradiation and hope to extend our knowledge of dislocation processes in titanium.

To ascertain the underlying mechanisms of the processes, we have conducted experiments to establish the dose and temperature dependence of the effects on mechanical properties, to determine the recovery kinetics of the hardening effects, and to measure the change in electrical resistivity due to irradiation.

The necessary equipment to produce irradiation at -196°C is now being designed and we have a proposal pending with NASA to support further research.

INFLUENCE OF TEXTURE ON FATIGUE OF TITANIUM AND TITANIUM ALLOYS

D. Rosenthal, W. Hanna

With the ever-growing use of titanium and titanium alloys in space technology, it appears desirable to extend our observations on the effect of texture on fatigue to this currently important type of metals.

The difficulty in preparing specimens for an adequate observation during testing may be one of the reasons why surface mechanisms in the fatigue of titanium have been less studied than in the fatigue of other matals. Our main effort was directed toward overcoming this difficulty. We faced two distinct problems: (a) surface preparation with a mirror polish for

microscopic observation; (b) suitable grain size for x-ray diffraction determination of grain orientation.

a. Surface preparation: We developed a successful method of surface polishing and described the method in our previous progress report; no further improvements are necessary for the moment.

b. Suitable grain size: The strain-anneal technique described in our July, 1966, progress report yielded a maximum grain size of about 2.4 mm in commercially pure titanium. This size was judged to be too small for a convenient exploration of individual grains by means of x-rays. Therefore, we directed our subsequent efforts toward production of a larger grain.

One of the limitations of the strain anneal technique is that the treatment must be carried out below 880°C, the temperature of alpha-beta transformation of titanium. Considering titanium's high melting point of 1,660°C the temperature of 880°C is probably too low to promote extensive grain-growth. As mentioned in our last report, large crystals of titanium apparently have been grown at higher temperatures in the beta region and they have been preserved in the alpha region by slow cooling through the beta-alpha transformation range. However, our own attempts, while yielding a suitably large grain size, could not prevent simultaneous contamination from the ceramic enclosure. Since the treatment was carried out in the furnace, we presume that the temperature of the enclosure was high enough to promote diffusion of silica from the enclosure onto the titanium specimen, despite the high vacuum of 10^{-6} mm.

Our work performed during the period of this present progress report was aimed at eliminating the danger of contamination by keeping the enclosure at a much lower temperature than the specimen. The zone induction heating equipment available in our processing laboratory was used for this purpose. In the first series of tests the specimen was kept at a high vacuum of at least 10^{-5} mm, and it was locally heated to about 1100°C by a slow moving induction coil which was wound around the pyrex tube enclosing the specimen. The temperature was estimated to ±10°C by an optical pyrometer. Unfortunately, metal deposition from the specimen onto the pyrex tube, not only blackened the wall but also caused parasitic induction heating and cracking of the tube.

In the second series of experiments, the specimen was sealed in an initally highly evacuated pyrex tube, but the pressure was allowed to build up during local heating, thereby substantially reducing the rate of metal deposition onto the walls of the container. As seen from the enclosed macrograph,

Figure 1, substantial increase of grain size could be achieved, but the ensuing rate of cooling was too high to prevent formation of the undesirable Widmanstatten structure following the beta-alpha transformation, Figure 2.

It follows from the above results that our future work logically should be devoted to the elimination of the objectionable Widmanstatten structure by either using chemically, instead of commercially, pure titanium, or by modifying the existing zone induction heating equipment to produce considerably slower rates of cooling. Neither of these solutions is feasible without additional resources. In an endeavor to secure outside support we are now reconsidering the use of the smaller grain size obtained by the strain-anneal technique last year. Our current work is aimed at securing whatever information is possible by subjecting specimens endowed with this smaller grain size to fatigue. The balance of the present grant along with a small additional grant from the University Research Committee will provide the necessary funds for student assistance.

AN INVESTIGATION OF ULTRASONIC PROPAGATION IN FERROMAGNETIC MATERIALS

R. Stern

At present we are investigating the loss of sound energy as an acoustic signal travels through a ferromagnetic material such as nickel or iron. This loss, and the speed of sound, depend on many factors. We intend to vary some of these factors by applying pressure, a magnetic field, and changes in temperature to the sample while making measurements. It has been found that a magnetic field causes changes in the physical dimensions of ferromagnetic materials; thus applying a magnetic field is equivalent to applying a pressure as well as the field. A critical part of our experiment will be to try to separate those effects which are caused by the pressure.

Three associated projects concerned with the application of the data resulting from the main part of the study will also be undertaken. All three are forms of solid state modulation devices.

We have designed and assembled a complete ultrasonic transmitting and receiving system and are using it to investigate acoustic propagation in polycrystalline nickel under conditions of changes in uniaxial stress. The unit is capable of producing a 5-watt cw/pulsed ultrasonic signal in the frequency range of 20 Hz to 500 MHz. However, at this time our investigations are in the range of 5-65 MHz. A 20-ton hydraulic press applies the

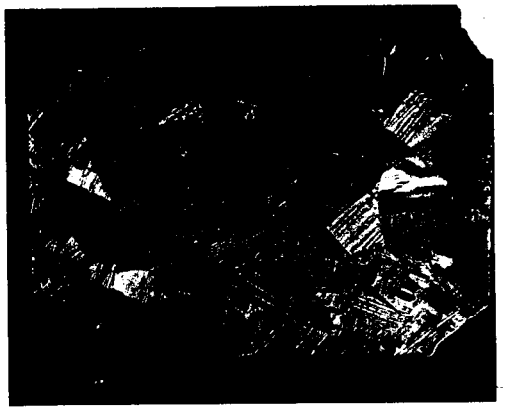

Figure 1

Production of large grain in commercially pure titanium by zone induction heating (x5).

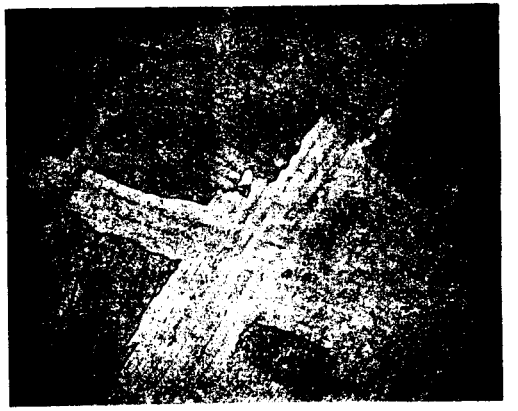

Figure 2

Widmanstatten structure in alpha titanium (x50).

stress to the material. Preliminary measurements have been made for both compressional and shear waves propagating in the sample.

We constructed a low-temperature facility and with this unit our temperature capabilities will be from 1.6°K to room temperature (293°K). We expect to have most of the magnetic field installation operating by June 1968. Thus our investigation of ultrasonic propagation will study four parameters -- frequency, temperature, magnetic field, and uniaxial or hydrostatic stress.

Information was mutually gained by the discussion of this project with the Gordon Research Conference, California Institute of Technology - Low Temperature Laboratory, and UCLA Department of Physics - Acoustics Group.

During part of this period Jeffrey L. Hahn, a Research Assistant, received support from this grant.

As a result of support for this project by NASA, we have been able to obtain a contract in the amount of $9,386 from the Office of Naval Research.

DEVELOPMENT OF FAR INFRARED SUPERCONDUCTING PHOTODETECTOR

T. F. Tao

Far infrared refers to those electromagnetic waves in the spectrum between the microwave and infrared. The radiation energy in this spectrum is extremely weak, making its study dependent on ultrasensitive detectors, most of which are bolometers with a relatively slow response time of the order of milliseconds. A fast-response quantum photodetector using doped germanium can detect wavelengths of up to 200 microns. For detecting radiations of longer wavelengths, only the Putley photodetector is available. It is made of a high purity n-type indium antimonide, cooled below 4.2°K and subjected to a magnetic field.

Our study is trying to use the energy gap of a superconductor to detect radiations of wavelength from 100 to 2000 microns and we anticipate a response time of the order of microseconds. In the last period we have made both the transmission grating filters and the Yoshinaga filters, and have aligned the spectrometer, although its calibration is still incomplete.

The tunneling studies of thin polymer films (N. Grossman, M.S. thesis) and of superconductor semiconductor junctions (M.

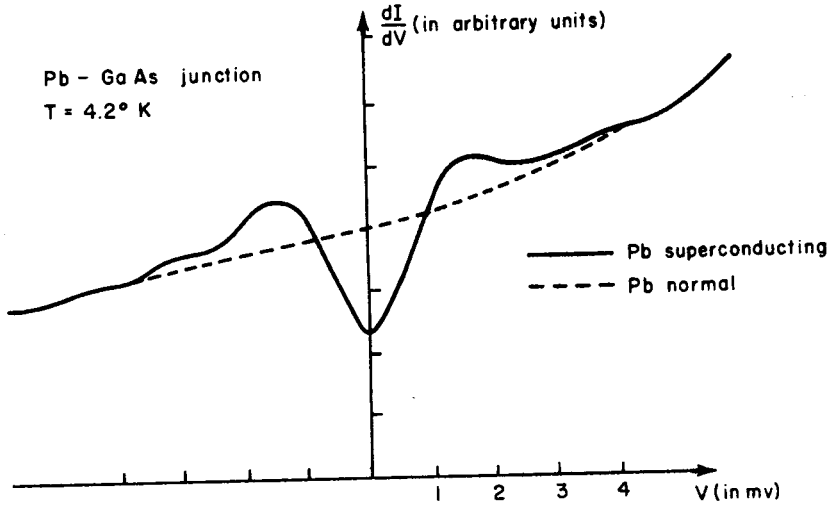

FIG.1 TYPICAL CONDUCTANCE—V TUNNELING CURVE

Weiss, M.S. thesis) are nearly completed. Mr. Grossman found that polymer films are not stable and he attributes this to ion migration within the film which contains many broken molecular bonds. The depletion layer of a metal semiconductor junction, however, is a good tunneling barrier. Figure 1 illustrates a typical tunneling curve (dI/dV versus V). Y. Hsia and T. Tao are working out a theoretical analysis for this tunneling from superconductor to degenerated semiconductors.

Once the spectrometer is calibrated, we can begin investigating the far infrared response of these junctions. Until that time, however, we are working with Dr. P. R. Bratt of the Santa Barbara Research Center to develop the indium antimonide electron bolometer for use in the far infrared spectrum.

Participating students in this project are: Ph.D. candidates A. Capell, whose thesis title is "Far Infrared Spectrometer and Photodetectors," and Y. Hsia, whose thesis title is "Study of CdTe-HgTe Alloys." Master's degree candidates are N. Grossman and M. Weiss.

SURFACE-WAVE PROPAGATION ALONG AN ANISOTROPIC COLUMN

T. F. Tao

There have been many studies on the wave propagations associated with anisotropic media, but a close agreement between theory and experimental results has not been established. In this study we are attempting to bridge this gap. The two types of anisotropic materials which have received a great deal of attention from microwave engineers and space scientists during the past decade are the ferrites and the gaseous plasmas which exist around space vehicles during re-entry. They are vastly different phenomena; however, their electromagnetic wave properties are quite similar in that they are described by a tensor permeability (or permittivity) of the same form. Basic understanding of how electro-magnetic waves propagate along or through such media are necessary to use such materials and/or to overcome any difficulties they may cause, such as re-entry blackout.

We are carrying out two studies in this area: (1) Backward surface waves. The high frequency permeability of ferrites and the high frequency permittivity of plasma become negative when magnetized by a d.c. magnetic field of certain magnitude. We have found that surface waves can propagate along such open columns of negative μ (or ε). These surface waves are characterized in that their phase velocites and group velocites are in opposite directions. They are called the backward surface

waves. Mr. J. Tully is studying these waves both experimentally and theoretically. (2) Measurement of permeability and permittivity by a nonperturbational technique. μ and ε of both the ferrites and plasmas at microwave frequencies are measured mainly by the cavity perturbation technique. The sample used must be small so that the perturbation calculation is valid. This method becomes very difficult when the frequency is increased. Mrs. Chiang, a Ph.D. candidate, is trying to develop a nonperturbational technique based on the wave propagation along a bulk waveguide made of these materials. Since there is no limitation of the smallness of the samples, this method will be useful at millimeter wave frequencies if successfully developed.

During this period, we have constructed a cesium plasma tube. However, testing is being held up because the d.c. power supply cannot heat up the tungsten button enough to ionize sufficiently the cesium vapor.

A paper was published in the June, 1967 issue of the J. Appl. Physics entitled "Electromagnetic Waves in Longitudinally Magnetized Ferrite Rods."

Students participating in the research project are Mr. J. Tully, who has completed his M.S. degree this June and is now a Ph.D. candidate, thesis title "Backward Surface Waves," and Ph.D. candidate Mrs. Y. F. Chiang, thesis title "Measurement of μ and ε by a Nonperturbational Technique."

We have received a National Science Foundation Grant for continued research in this area entitled "Surface Wave Propagation Along Anisotropic Rods at Millimeter Wavelengths."

ANALYTICAL METHODS FOR THE OPTIMUM DESIGN OF STRUCTURES

J. E. Taylor

In our investigations, design refers to the distribution of material in a structural configuration. The goal of optimization is to determine the most efficient distribution of material for structural function. Within this description, the type of problems we are considering include optimal design relative to buckling or vibration, and design to maximize elastic or collapse capacity. We are seeking general methods for the analytical formulation of these various problems and are treating examples of the design of bars, frames, and plates.

A recent result of our work provides us with a method for the formulation of problems where the goal of optimization is to maximize the lowest natural frequency of vibration of a

structure. The approach used represents an extension of familiar energy methods into a procedure for the design problem. The technique is demonstrated for the axial vibration of a bar, and for beam vibration problems. Also, a proof of optimality is given. This work appears in the list of published manuscripts.

The manuscript "Problems of Optimal Structural Design," (to appear in J. Appl. Mech.) reports the application of a variational approach to four categories of problems: Optimum collapse structures; maximum lowest frequency of vibration design; maximum stiffness design; and optimum design relative to buckling. Attention is limited to structures for which stiffness is a linear function of unit weight or volume of material. Example solutions of each type of problem are given, along with proofs of optimality.

In our work presently under way, the above described methods are to be modified to accomodate inequality constraints on cross-sectional dimensions. Once this is accomplished, it will be possible to obtain optimum designs within a specified allowable measure of strength of the material in the structure. We will try the method on various framed, plate, and shell structures.

Our project has led to collaboration with Professor William Prager at the University of California, San Diego. Students participating and financially being supported by this grant are Dominic Ma, Master's candidate, August, 1967, and Frank Tso, Ph.D. candidate, August, 1967.

The research initiated under this grant is to be continued under a two-year $39,900 grant from the National Science Foundation.

HUMAN PERFORMANCE IN ADVERSE ENVIRONMENTS

G. Weltman, G. Egstrom

The first phase of our study of the psychological stress in novice divers has been completed, as described in the last report. We have presented some results of our work at the Western Psychological Association Meeting in San Francisco and at the 8th Annual Symposium on Human Factors in Palo Alto. Our work on this subgrant has been instrumental in our obtaining a $25,103 contract with ONR for "Studies in Underwater Work Measurement Techniques." The methodology developed during our first phase has been applied to the ONR work and we hope to obtain additional ONR funds for studies on stress and attention.

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NUMBERICAL INDEX TO GRANTS AND CONTRACTS